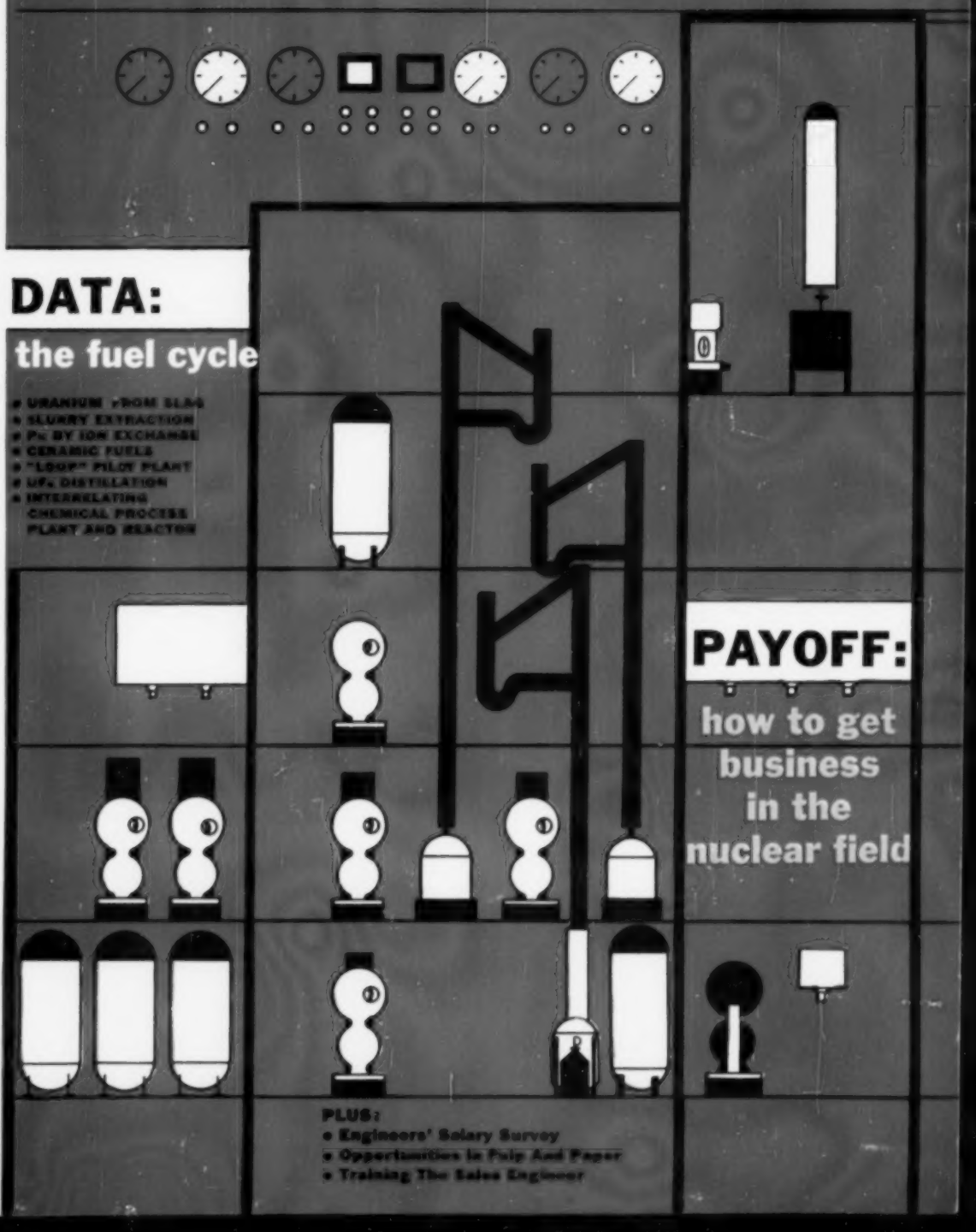
FEBRUARY 1957

CHEMICAL ENGINEERING PROGRESS

NUCLEAR SPECIAL



DATA:
the fuel cycle

- URANIUM FROM SLAG
- SLURRY EXTRACTION
- Pu BY ION EXCHANGE
- CERAMIC FUELS
- "LOOP" PILOT PLANT
- UF_6 DISTILLATION
- INTERRELATING CHEMICAL PROCESS PLANT AND REACTOR

PAYOFF:
how to get business in the nuclear field

PLUS:
- Engineers' Salary Survey
- Opportunities in Pulp And Paper
- Training The Sales Engineer

Philadelphia CONGRESS PROGRAM

•

ATOMIC EXHIBITORS

PROVEN

BY PERFORMANCE

INVENTA-VULCAN

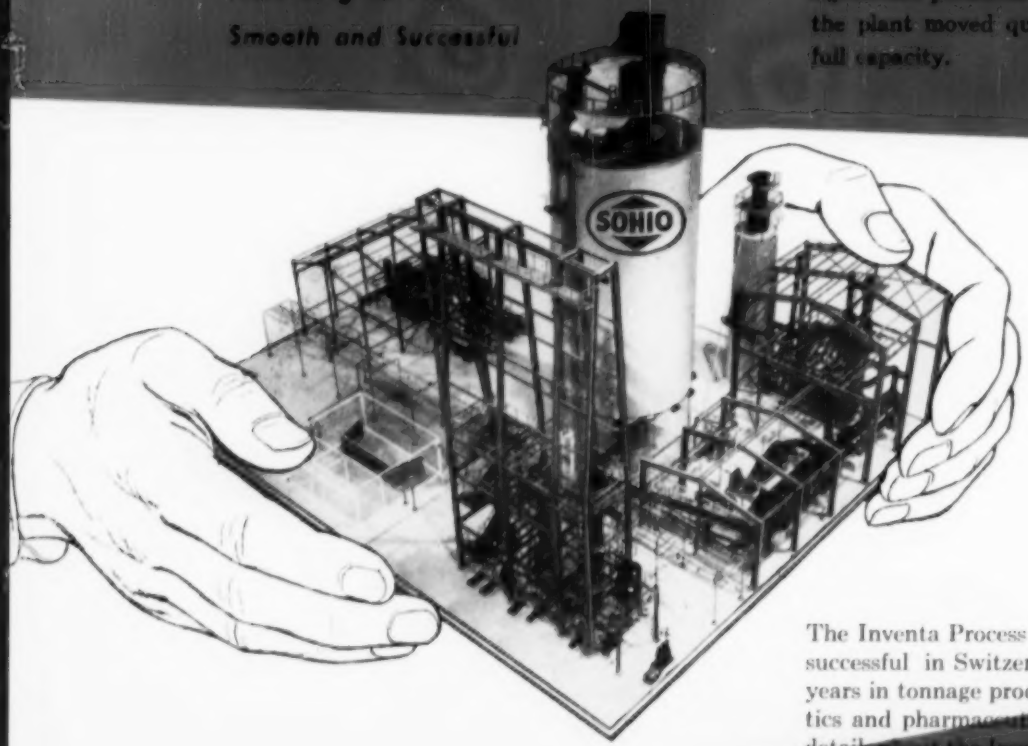
UREA PROCESS

Sohio Startup
According to Plan—
Smooth and Successful

The first Inventa-Vulcan urea plant in the United States is now on stream. This new plant was designed and built by Vulcan Engineering Division—licensors of the Inventa Process in the U. S. and Canada—for Sohio's $17,000,000 petrochemicals installation at Lima, Ohio.

Within six hours after startup high quality urea was produced. Ease and reliability of operation were demonstrated. Startup produced first urea solutions and then prills for agricultural purposes exactly as planned.

Corrosion, traditionally present in urea synthesis, was conspicuously absent, as were clogged lines and contaminated product. No significant problems were encountered and the plant moved quickly and smoothly to full capacity.



VULCAN

The Inventa Process has been commercially successful in Switzerland for more than six years in tonnage production of urea of plastics and pharmaceutical grades. Additional detail about the Inventa-Vulcan Urea Process may be had by writing to the Vulcan Engineering Division.

VULCAN ENGINEERING DIVISION

VULCAN-Cincinnati, Inc. General Offices and Plant, CINCINNATI 2, OHIO
(Formerly THE VULCAN COPPER & SUPPLY CO.)
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VULCAN ENGINEERING DIVISION • VULCAN MANUFACTURING DIVISION • VULCAN CONSTRUCTION DIVISION

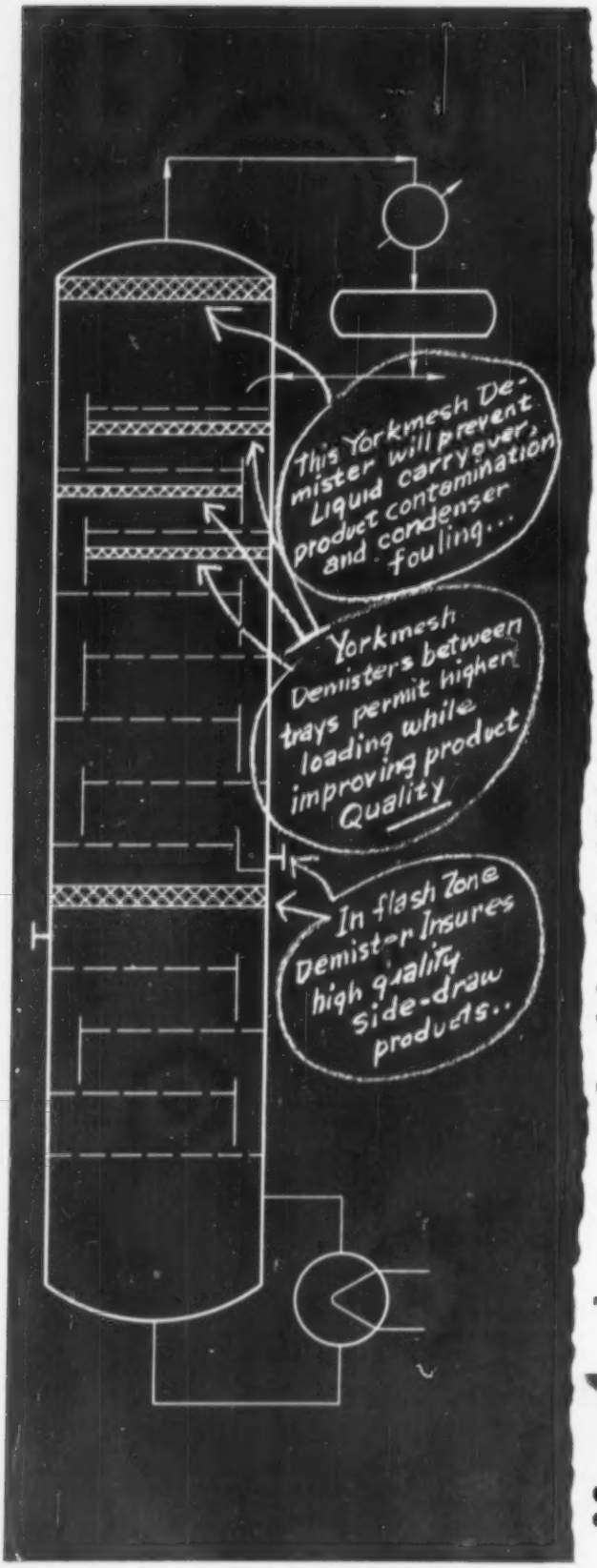
Chemical Engineering Progress

what's in this issue

February, 1957 • Volume 53, No. 2

(Continued on page 5)

departmental features



How to INCREASE THRUPUT in DISTILLATION EQUIPMENT...

The efficiency of separation and thruput capacity of distillation equipment can be significantly improved by the use of YORKMESH DEMISTERS.

Overhead quality is improved by eliminating liquid entrainment containing high boiling impurities.

Increasing thruput in existing equipment often results in decreased product quality. YORKMESH DEMISTERS installed between trays will permit increased thruput capacity while maintaining or improving quality of overhead product.

The advantages of positive separation of liquid from gas are obtained with negligible pressure drop.

Send details on your operating conditions and let YORK engineers take the responsibility of improving the performance of *your* equipment.

Similar improvements in process efficiency are effected by the clean separation of vapor from liquid in:

Vacuum Towers • Flash Tanks
Distillation Equipment • Evaporators
Absorbers • Scrubbers • Steam Drums

WRITE for Bulletin 17 and a complete list of the many case histories available from our technical library.

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Cover by Milton Wynne Associates

what's in this issue

(Continued from page 3)

Check your drawings and you may find that you require all of the stainless steel items shown here—plates, heads, tube sheets, discs, forgings, flanges, rings, special patterns, bars, and sheets (#1 Finish) in the heavier gauges. When you buy all these material components from one source you save time, effort and money.

Your assembly costs are kept to a minimum when you use Carlson's abrasive cut material. Cleaner edges mean less true-up time on the job. There is no heat-affected zone because little heat is developed during the cutting. Fabrication is easier and the finished product is of the highest quality, more dependable in use.

Who pays freight on "offcuts" you can't use? No one, when you use Carlson's service for cutting plate to shape, ready for your fabrication. Plate is sheared, sawed, flame or abrasive cut and machined to your specifications. Eliminating freight charges on excess material lowers your costs.

There's the matter of delivery which also means time and money to you. As specialists in stainless steels, Carlson has the diversified equipment and the technical and practical knowledge to produce the plate or shapes you want, the way you want them with delivery as promised.

Stainless Steels Exclusively

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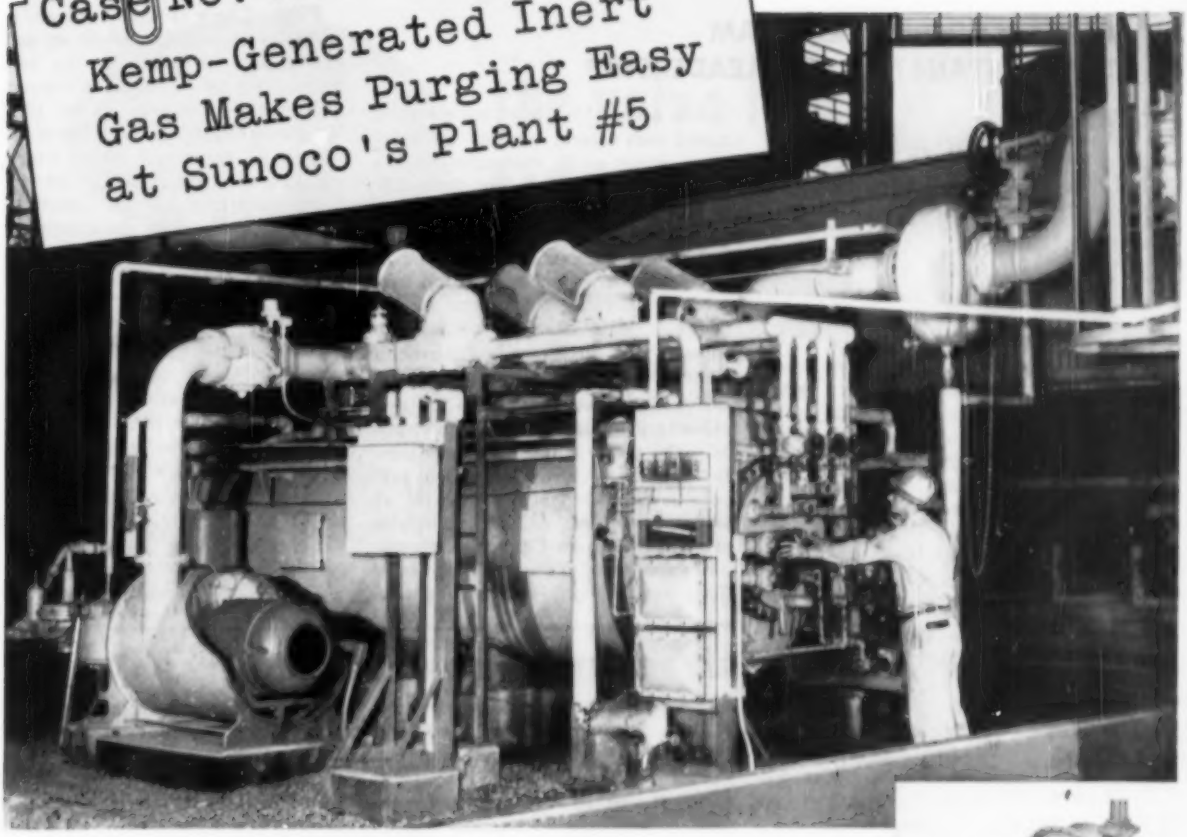
DISCS • FORGINGS • FLANGES • BARS AND SHEETS (No. 1 Finish)

Case No. 57

Kemp-Generated Inert Gas Makes Purging Easy at Sunoco's Plant #5



How Sun Oil's "Magic Mill" at Toledo operates with 'round the clock safety

There's no *one* word that strikes terror in the hearts of oilmen everywhere more quickly than F-I-R-E! To combat this threat at the Sun Oil Co.'s giant refinery at Toledo, Ohio, constant vigilance, checks and inspections are the answer. And the liberal use of inert gas for purging pipelines, tanks and crackers is essential to this safety maintenance.

Kemp selected to do the job

When plans called for *doubling* plant production in 1950, a new Kemp Generator (see above) was installed to insure adequate inert gas production. Fast-starting, easy-to-operate, this Kemp unit more than filled the bill. Today tanks and lines are periodically purged for inspection and cleaning *as often as needed*. And thanks to its 60,000 cu. ft. per hr. Kemp Inert Gas Generator, Sunoco enjoys ***exact analysis*** inert production that meets all its purging requirements.

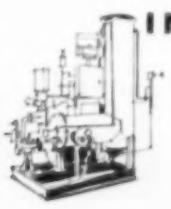
Let Kemp help you, too

If you have a purging or blanketing problem, why not let Kemp Engineers give you the same helpful advice used so profitably at Sun Oil's Toledo refinery. It costs you nothing to investigate. And it may save you money. Find out how Kemp's wide range of dependable, low-cost Generators (complete with the latest fire checks and safety devices) offer you the best way to solve your problems.

Photo above shows close-up view of Kemp Industrial Carbureter, the heart of every Kemp installation. Assures complete combustion... without waste, without tinkering. Reduces installation costs, simplifies maintenance.

***For more complete facts and technical information, write for Bulletin I-10 to:* C. M. KEMP MFG. CO., 405 E. Oliver Street, Baltimore 2, Maryland.**

KEMP OF BALTIMORE



INERT GAS GENERATORS

CARBURETORS • BURNERS • FIRE CHECKS METAL MELTING UNITS • ADSORPTIVE DRYERS • SINGEING EQUIPMENT

Noted and quoted

AN EIGHT-POINT PROGRAM TO MAINTAIN NUCLEAR LEADERSHIP

Lewis L. Strauss, Chairman, U.S.A.E.C.

Following months of heated discussion of the relative roles which government and industry should play in our nuclear power development program, Lewis L. Strauss, Chairman of the Atomic Energy Commission, has come forth * with an eight-point program which will be taken by many as an indication of the latest thinking on the part of that body.

Said Strauss, "Our goal for progress is not one of building an arbitrary number of plants, or a fixed figure of installed kilowatts of generating capacity. Our objective, which seems to us more prudent and more constructive, is to develop the *technology* of nuclear power reactors of various types and sizes to the point where they will be economic in competition with kilowatts produced from conventional fuels.

"This broad objective would be attained under the eight-point program which I propose and which would include the following steps:

First: That the Commission, as quickly as possible, call for a third round of proposals under the Power Demonstration Program, but with this significant departure from past procedure: each proposal would be considered individually and acted upon by the Commission as it is received. No proposal would be considered that did not promise completion of the proposed plant before a target date of June 30, 1962.

Second: That no limitation of any kind be placed upon either the sizes or types of the nuclear plants proposed for construction. The governing criteria would be whether a project promised to make significant contributions toward achieving cheap, abundant, and safe nuclear power.

Third: That, in considering the proposals, the Commission give priority to three particular types of reactors, in this order: 1) a large-scale reactor fueled with natural uranium and using heavy water as its moderator, such a reactor to be of not less than 100-thousand electrical kilowatts capacity; 2) a large-scale, fluid-fuel reactor system based on aqueous solution and/or slurries of uranium and/or thorium-bearing materials, this reactor also to be of at least 100-thousand kilowatt capacity; 3) three small-scale reactor projects of varying new designs.

Fourth: That the Commission give industry the first opportunity to undertake the construction of these power reactors. However, if acceptable proposals were not forthcoming on all the specified types within a reasonable period of time, the Commission would take prompt and positive steps to build those reactors on its own initiative. The same target date of June 30, 1962, would apply to any Government-built plants.

Fifth: There is both need and opportunity to move ahead at an accelerated pace, not only in the actual construction of full-scale experimental and prototype nuclear power plants, but also in expanding our store of technology by means of more complete research and development. Therefore, I am proposing that the Commission substantially increase the existing opportunities for Government assistance by assuming a greater share of the cost of research and development as distinct from actual construction costs.

Sixth: That further assistance be provided in the form of a phased waiver or reduction of the use charges presently made by the Commission in connection with the leasing of nuclear fuels for commercial reactors.

Seventh: That the Commission take action at an early date to establish the charges at which it will be willing to enter into firm commitments for

(*Continued on page* 12)

* In an address before the American Nuclear Society, Washington, D. C., December 11, 1956.

DO POWER REACTORS OFFER HEALTH HAZARD?

"The prospective enormous and rapid expansion of nuclear power [offers serious concern for the public health]. Even a modest nuclear power program will bring into existence vastly greater quantities of radioactive materials than are produced in the development of nuclear weapons. Technical ingenuity of the highest order will be required to control these operations so that at no time are dangerous quantities released to the environment. Good techniques are already available but continued development will be necessary. . . ."

So concluded * *J. C. Bugher, M.D., Director of Medical Education & Public Health, The Rockefeller Foundation, who recently analyzed the health situation as follows (in brief):*

It is well established that injury [to the human being] from appreciable radiation exposure has two components. One is transient in character and, assuming that the injury has not been sufficient to cause death, will eventually permit complete recovery. The second component is one of permanent injury. . . . Severe acute illness from heavy exposure points clearly to the circumstances of the exposure and the mode of prevention. It is the long-continued exposure of low intensity which may gradually build up far more permanent cumulative injury . . . health considerations . . . thus have to do with problems of continued low-level radiation without acute illness. . . .

Whole body exposure to radiation is appreciably different from the irradiation of a single part. The tolerance of the entire individual to radiation is much less than that exhibited by any single organ or component of the body. [In this connection, there are] two broad classes of biological effects. The first . . . affects the individual himself . . . may be spoken of as the *somatic* effects. . . .

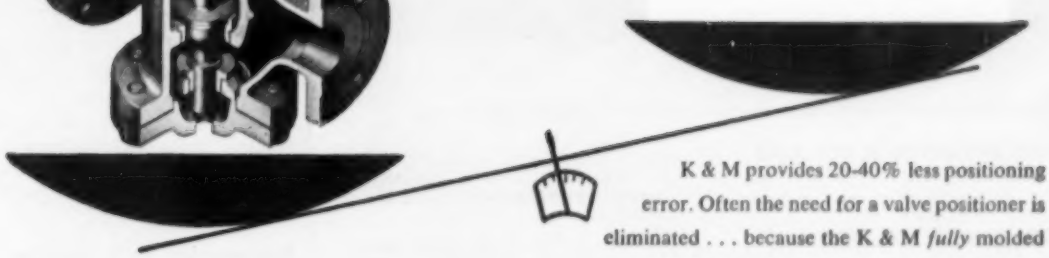
A very important manifestation [of *somatic* effects] is . . . decreased life span, . . . quantitatively related to the total amount of radiation exposure. The measure of this effect is an increased rate of general aging. The exposed population simply grows older at a rate greater than that of the normal for that population. Evidence is accumulating that this is probably the most sensitive indication of population injury that is available, and it is probable that studies of whole populations will demonstrate changes which would be imperceptible on the basis of individual observation. . . .

(*Continued on page* 16)

* Based on an address by Dr. Bugher, presented before the National Citizens' Committee of the World Health Organization, November 14, at Atlantic City, N. J.

the valve that LIKES TO BE COMPARED

Is a valve positioner always required?



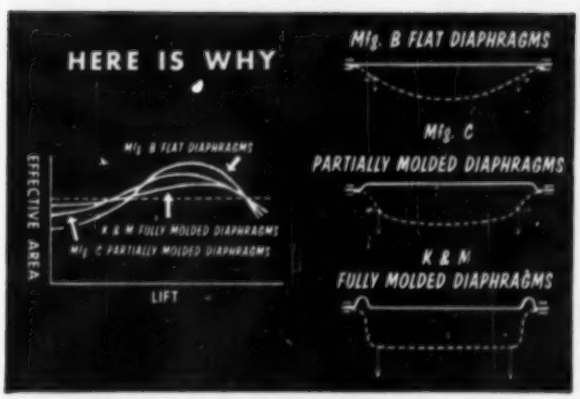
K & M provides 20-40% less positioning error. Often the need for a valve positioner is eliminated . . . because the K & M *fully* molded diaphragm gives the most constant effective diaphragm area.

K & M precision positioning also derives from long stem travel . . . lift that equals or exceeds any comparable valve . . . plus the highest power factor in the industry.

Behind it all lies one fact: K & M Control Valves are not *adapted* to high lift, they are *designed* for it. Throughout the entire range of valve travel . . . positioning is accurate and undistorted . . . control increments are finer with minimized positioning error.

Write for the K & M Valve Data Catalog, Bulletin CV-53.

77th Anniversary . . . Oldest U. S. Pressure and Level Control Valve Manufacturer



With K & M *fully molded* diaphragms, virtually all components of force are vertical. Added to this, K & M gives the highest power factor (diaphragm area x lift) for precise valve positioning.

diaphragm control valves

KIELEY & MUELLER, INC.

64 GENUNG STREET, MIDDLETOWN, NEW YORK

K&M

Noted and quoted

(Continued from page 10)

the chemical processing of nuclear fuel elements in Government facilities.

Eighth: That the Commission's new and more elastic partnership with industry be made broad enough to include reactor projects designed for commercial uses other than electric power."

Coming Events?

It is significant that, just four weeks after the Admiral spoke, the AEC implemented part of his plan through its announced "third round" of invitations for nuclear power plant proposals. These include provisions that coincide almost identically with the first three points of Strauss's plan.

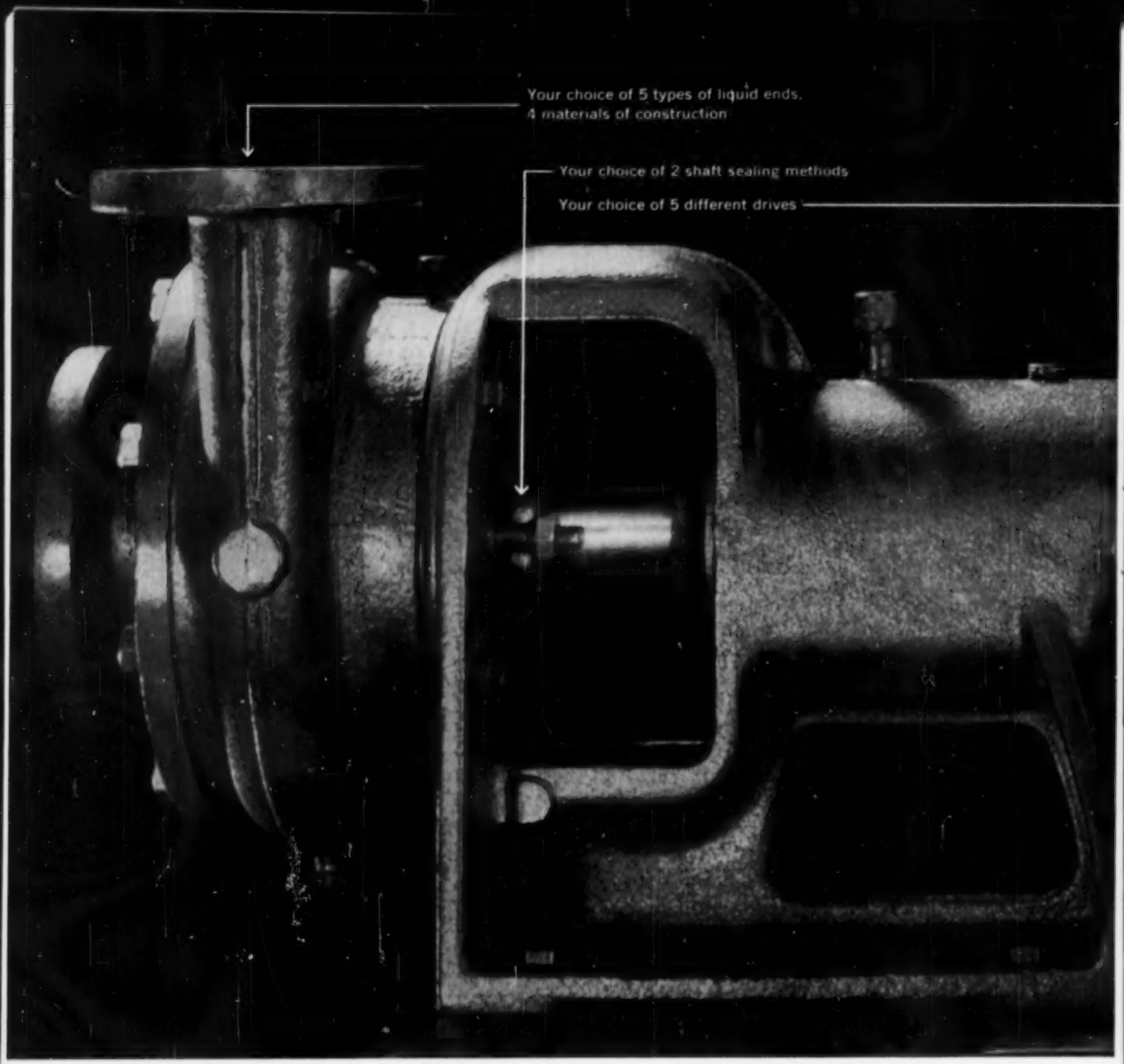
Under these new invitations, it is stipulated that construction of the plants proposed must be completed by June 30, 1962. Considering the time necessary for design, procurement, and construction of such facilities, it is evident that swift and effective action is being demanded of private industry to meet what is, in effect, an early deadline.

Will the alternative, if private industry does not respond with sufficient proposals, be that point four of Strauss's program would be put into effect: "that the Commission take prompt and positive steps to build these reactors on its own initiative?"

Engineering in Transition

[Higher professional standards for the engineer] will never be accomplished through any movement which detracts from the individual. The position voiced by the majority of professional engineers today in opposing collectivism upholds this statement. In lieu thereof, there must be another approach, and I should like to submit, as a partial solution at least, that the engineering profession as such, including all members of professional societies whether individually employed, employees of corporations, or governmental or civil employees, take a firm stand and act as one man for the recognition of the engineer. This can be done only through an educational program wherein the public is given the facts. Once informed it may understand and support the principles which the profession itself believes in. . . . The contribution of the engineer to the general welfare of society and the economic growth of America can not be overstressed.

Condensed from a talk "The Changing Engineering Profession" by Frank W. Jessen, The University of Texas



THE PUMP THAT'S RIGHT

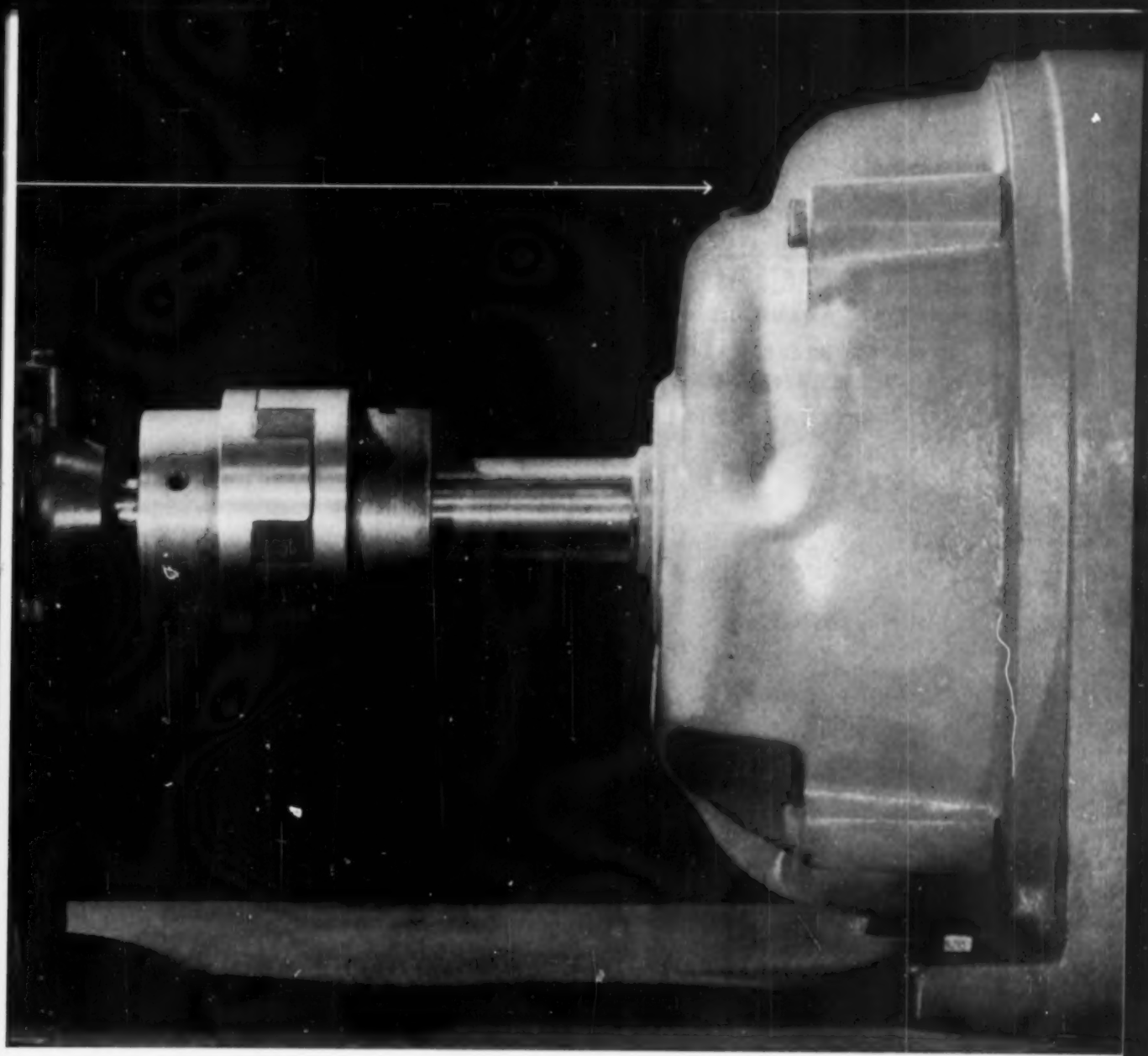
Chances are that Worthington's Standard End Suction Centrifugal (SESC) line will meet your strictest requirements for 49 out of every 50 jobs. Only once will you have to buy a non-standard pump.

"CUSTOM BUILD" AT NO EXTRA COST. An SESC pump gives you standardization *plus* versatility. You can literally "custom build" your pump to get exactly the right features.

For example, you have a choice of materials of construction—iron, steel, bronze, Worthite* and combinations of these—to meet all types of corrosive conditions.

Hydraulic coverage can't be matched. There are 120 different sizes with ratings up to 2,700 GPM and 550 ft. head. You have a choice of stuffing box or mechanical seal operation. Both open and enclosed impellers are available.

SLASH INVENTORY, REDUCE DOWNTIME. After you have installed an SESC pump, you reap the benefits of standardization. Since only four bearing frame sizes are used for the 120 pumps in the line, spare parts inventory can be cut as much as 50%. When repairs or conversions are necessary, parts interchangeability can often mean drastically reduced downtime. And since the entire line is built to the same basic design, maintenance work is greatly simplified and costs lowered.



49 TIMES OUT OF 50!

Your Worthington representative has a unique SESC Demonstrator that explains the many advantages of pump standardization. Ask him to show it to you, or write to Section SP-73 for Bulletin W-300-B4B. Worthington Corporation, Harrison, New Jersey.

*A high nickel, high-chromium, low-carbon alloy steel. Trademark Reg. U. S. Pat. Off.

WORTHINGTON

70,480 COMBINATIONS. *Worthington's SESC line offers you a broad selection of pump modifications to choose from. In all, there are more than 70,480 combinations...all built from standard, stocked parts and available for prompt delivery at competitive prices.*

Noted and quoted

(*Continued from page* 10)

[From] observation of human experience both in the U. S. and Japan, it appears that 100 roentgens of gamma radiation to the whole body may shorten life expectancy by an amount between half a year and two years . . .

The second, or *genetic* [transmitted] effects, . . . produce mutations. . . . [Their frequency] is approximately proportional to the [total dose] of radiation. . . . Modern geneticists look with concern on any appreciable increase in the frequency of mutations in man . . . [agree that] radiation exposure should be kept to the lowest possible amount. . . .

To appreciate the magnitudes involved . . . consider the character of our present radioactive environment. The world is radioactive . . . in the earth's crust are found large amounts of [radioactive] elements. . . . All natural potassium . . . [all] carbon . . . [contain] radioactive isotopes, [contributing an appreciable increment in the total dose to which people are exposed.] [From] cosmic radiation . . . all living things on earth are constantly bombarded by this celestial radiation. . . .

From all these *natural* sources . . . individuals may receive a total exposure in a lifetime of the order of 10 roentgens equivalent. . . .

Man-made components [have added] to the general exposure [as follows]:

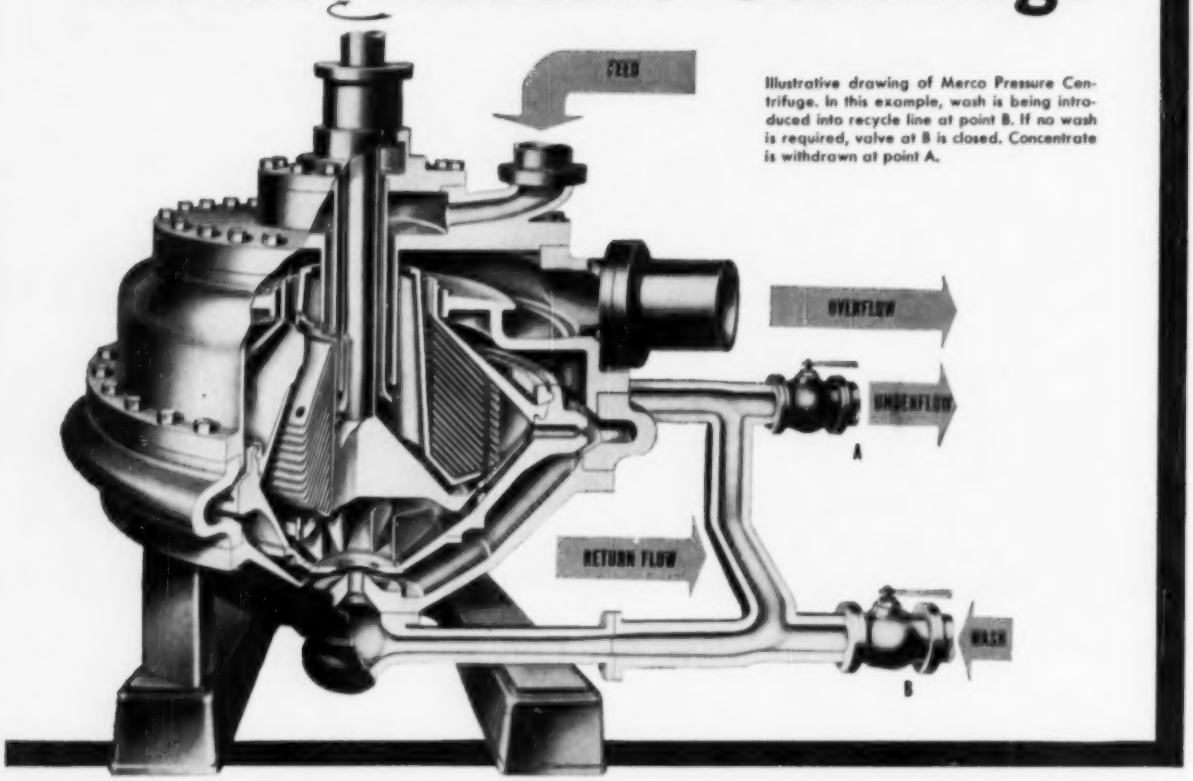
. . . nuclear detonations . . . amount to approximately one per cent of the lifetime exposure of people to natural radiation of the earth and cosmic sources . . . X-ray . . . may amount to three or four roentgens during the reproductive lifetime . . . Strontium-90 . . . now in existence in our environment as a result of nuclear detonations . . . [is distributed] over the entire United States [at an] average value of approximately 10 millicuries per square mile . . . In skeletons of all persons now living, some values reach a level of about 1/1000 of one microcurie . . . 1/1000 of the amount which is presently considered the permissible body burden . . .

The importance of the protection of the radiation worker was stressed from the beginning of the U. S. atomic energy program. Enormous efforts have been expended by the AEC to ensure that the public health should receive primary consideration in all of its operations. This has involved vigorous support of fundamental . . . research. . . . It is through careful research and thoughtful planning . . . by the freest possible interchange of scientific information and operational experience . . . that the continued expansion of the atomic energy industry can occur within the limits of safety for the people of all lands.

NOW

Centrifugal Separations under pressure conditions with the new

Merco Pressure Centrifuge



Illustrative drawing of Merco Pressure Centrifuge. In this example, wash is being introduced into recycle line at point B. If no wash is required, valve at B is closed. Concentrate is withdrawn at point A.

Newest development in wet processing equipment, the Merco Pressure Centrifuge is designed for all continuous centrifuging applications at pressures up to 110 psi. Key to pressure operation is a specially designed housing closure that has been exhaustively tested at pressures two to three times the guaranteed figure of 110 psi. Equally important, this new unit incorporates the unique Merco "Return Flow" principle for maximum operating flexibility. Under centrifugal forces thousands of times higher than gravity, even the smallest particles in the feed "sink" rapidly outward and are continuously expelled through fixed open nozzles in the rotor. A controlled portion is withdrawn as finished concentrate and the remainder becomes a return flow to the rotor. Wash, if desired, is introduced to the return flow line . . . clear, excess liquor overflows out the top of the unit.

If there's a step in your flowsheet involving concentration, washing, clarification, soluble recovery, or classification *under pressure*, there is a good chance that this new tool will prove useful. Bulletin No. 2600, just off the press, describes the Merco Pressure Centrifuge in detail. For your copy, write Dorr-Oliver Incorporated, Stamford, Conn.

Check these positive advantages . . .

Pressure Operation — Concentration, washing, clarification, soluble recovery or classification can be carried out under pressure.

No Solids Build-up — All solids entering the unit are continuously discharged. Return flow flushes solid material at periphery of rotor.

No Nozzle Clogging — Return flow principle permits nozzle flow 2 to 10 times as great as the underflow actually withdrawn. Merco nozzles will discharge particles as large as 1/32 inch.

Practical Design — All separating conditions are controlled externally. The unit is equipped with a sturdy housing which has been X-rayed and hydrostatically tested.

Merco T.M. Reg. U. S. Pat. Off.

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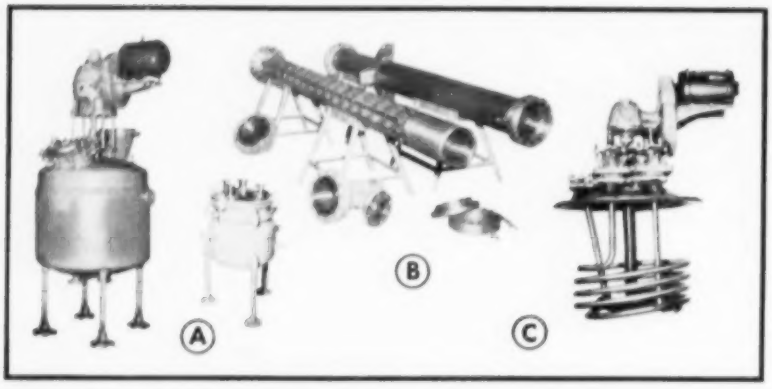
Corrosioneering News

Quick facts about the services and equipment available to help you reduce corrosion and processing costs.

Published by The Pfaudler Co., Rochester, N.Y., U.S.A.



A. Pfaudler titanium reaction kettles for high-temperature processing.
B. Pfaudler packed floating head titanium heat exchanger.
C. Pfaudler titanium loop coil for use in titanium reactor.

When should you use titanium process equipment?

Titanium, a relatively new material of construction, shows great promise in reducing corrosion costs under severe chemical conditions.

As corrosioneers, Pfaudler has studied its characteristics, developed welding techniques, designed and built quite a range of titanium process equipment. Some are shown above and others are being fabricated now.

Because production costs of titanium have been greatly decreased, titanium should now be considered as a material of construction wherever it is economically feasible to do so. It has superior resistance to nitric acid solutions at high temperatures, chlorinated organics and inorganic chloride solutions, and shows excellent resistance to mixtures of sulphuric and nitric acids and also to aqua regia.

There are also other materials which provide excellent chemical resistance, among which is Pfaudler glassed steel. Each case should be considered on its own merits.

Our main point is this: When you are up against any kind of a corrosion problem, Pfaudler is ready and anxious to give you the benefit of its 73 years of experience in designing and fabricating equipment that will do the best job at *the lowest over-all service cost*. If titanium is indicated, you can rely on Pfaudler know-how to do just that. Your inquiries are welcomed.

Copper and copper alloy equipment . . . For services involving acid solutions of low oxidizing capacity, copper and copper alloys may be the best answer to your problem. Pfaudler's long experience in building copper vessels and heat exchangers assures you of top-quality engineering and workmanship. You will also find Pfaudler prices competitive. Let us quote on your requirements for equipment of this type.

Glassed steel for the petroleum industry

The petroleum industry, like chemical processing, finds in glassed steel equipment a material of construction which is proving most economical in the battle against corrosion.

Great improvement in the resistivity of Pfaudler glass and its application to many different types of open hearth steel designs, are mainly responsible for this trend. Pfaudler glass, now resistant to all acids (except hydrofluoric) and to alkaline solutions to pH 12 at 212° F., provides about as much flexibility as you can find in any one material of construction.

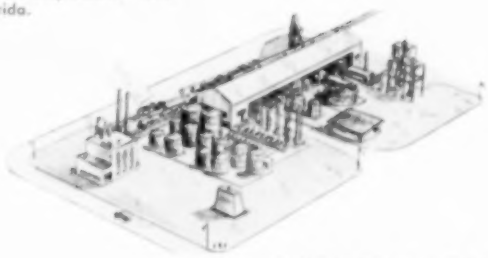
Used in the form of reactors, columns, settlers, mixers, storage tanks, pipe, fittings and valves, Pfaudler equipment is giving excellent service for reactions involving hydrochloric acid, chlorinated solvents, pesticides, vapor degreasing solvents, etc. It is also used in the hydration of olefins,

to prevent corrosion by sulphuric acid, in certain phases of producing cumene-derived phenol and by-product acetone in polyester resins and synthetic fibres.

Installations of Pfaudler glassed steel polymerizers are so numerous that standardized designs have been developed. Glassed steel can be cleaned quickly after each run: a build-up of product within the vessel is easily prevented.

In petroleum refining operations, corrosion during crude distillation has been minimized. Glass helps to prevent passage of hydrogen to the steel surface, eliminating atomic hydrogen attack. There are other applications too numerous to include here. May we send you more information?

Artist's conception of a five million dollar zirconium plant now under construction by NRC Metals Corporation, near Pensacola, Florida.



HOW TO GET BUSINESS in the NUCLEAR ENERGY FIELD

J. W. Blanton | NRC Metals Corporation,* Cambridge, Massachusetts

New business is a prime objective of American industry. Opportunity for new business in the nuclear energy field has been indicated many times by officials of industry and of government. Little doubt therefore remains that such opportunities exist and will continue to present themselves. However, since in all progress there are initial problems to be solved, so in the nuclear energy field a specified company must not only face the problem of the *how, when,* and *where,* but also, in the final analysis, must make its own decision.

National Research Corporation, the subject of this article, recently entered the field by undertaking the production of zirconium and hafnium metal. A review of the sequence of events, and some of the major business decisions involved, will prove helpful to an understanding of how such a venture in the nuclear field may be accomplished. It should be pointed out at this point that the meaning of 'business in the nuclear energy field' intended here concerns production of goods or services which are primarily used for nuclear energy applications, and not for the supplying of conventional goods and services generally used in other industries.

A characterization of the firm under study here and a definition of its resources—technical, managerial, and financial—also seem in order.

National Research Corporation is an independent, commercial organization incorporated in 1940 with the aim of launching new business enterprises. About half of its nearly 600 employees are in the Research Division engaged in engineering, commercial development, and research. The rest of the personnel are associated with the Equipment Division which manufactures special process apparatus, primarily industrial high vacuum equipment.

Besides the Equipment Division and the Research Division, the company has several affiliates. It holds an interest in a German firm producing vacuum equipment, and also an interest in a chemical firm, which produces ammonia, nitric acid, and vinyl chloride polymers. The corporation also formed a metals-producing firm and a fruit juice-concentrating firm, both using vacuum processes.

National Research is strongly technically oriented. Its founder and president is a physicist by training and a business man by nature. The four vice presidents, including the financial vice president, are all technically trained. In addition the staff includes some top scientists in their field.

The major research emphasis has been in extractive and process metallurgy, but considerable work has been done in applied physics and in organic, inorganic, and physical chemistry. Since 1941 the company, working on various aspects of the atomic energy program and studying such material problems as vacuum melting and casting of special metals and alloys and the production of high purity metals, has developed special vacuum equipment. Specific examples are the K-25 gas diffusion plant at Oak Ridge, Tennessee, and the equipment for uranium and thorium metal plants. A necessary adjunct to this work was the development of analytic methods for measuring minute impurities in metals and alloys.

In 1950 a major research program was initiated on a new process for the production of titanium metal. The firm in the spring of 1955 formalized its interest by establishing a Nuclear Energy Department as a part of its Commercial Development Department.

This background information should prove enlightening in examining the rather diverse nuclear energy field to determine where the resources of such a firm could be fully and profitably utilized.

Two results are derived from peaceful nuclear fission: heat and fission products.

The major applications of nuclear heat have to do with the production of electricity by existing electrical utility companies, and with propulsion.

The processing of by-product fission materials and the utilization of these materials in such applications as food sterilization, medicine, instrumentation, and as catalysts in chemical reactions are of such importance that considerable business will be based on these materials.

Heat and Power

It was reasonably clear that the firm's interests might be in supplying materials or services connected with the exploiting of the heat and power from nuclear fission. The design and construction of major power plants either for generation of electricity or for propulsion were certainly beyond the firm's scope for two reasons: namely, from the financial strain involved and also from the lack of adequately equipped technical personnel. The heat and power area was crowded and will probably become more so. It is practically essential for companies active in the field of electrical power generation to enter the field from a *defensive* point of view. Production and sale of experimental nuclear reactors were perhaps within the firm's capabilities but this seemed logically to be an adjunct to the design and construction of major power plants. Furthermore, National Research already was reasonably heavy in the equipment business by virtue of the vacuum equipment production, and hence the interest lay more in supplying consumable materials.

Fuel Reprocessing and Fuel Element Fabrication

Fuel reprocessing and fuel element fabrication were two areas which were also considered. Fuel reprocessing is of considerable interest and the firm is following it carefully since technically it is along the lines of its metallurgical background. *How* and

* Subsidiary of National Research Corporation.

when it might be possible to commercialize in that area remains to be determined. Fuel element fabrication is largely a mechanical operation requiring heavy capital equipment and appears more suitable for those who make special films and sheets.

Reactor Materials

As the reader probably knows, there are many different materials used in nuclear reactors. Eliminating the conventional materials such as cement, iron, lead, aluminum, stainless steel, and considering only those of a somewhat specialized nature, one comes up with about a dozen materials: namely, uranium, thorium, tantalum, niobium, bismuth, boron, zirconium, hafnium, molybdenum, titanium, beryllium, and rare earths. It was apparent that titanium, zirconium, and hafnium, all similar chemically, were of immediate interest in view of the extensive research program that the firm had underway on titanium—a program on which there has been spent some six million dollars. Research activities had emphasized titanium but included work on other metal projects. It is well to note that technological development is rapid in the nuclear energy field, and any one material may be made obsolete in a short period of time. Thus, the group of metals and not just zirconium was deemed of greatest practical interest.

Where, How, and When

From the foregoing analysis the firm's *where* in the nuclear energy field was reasonably well defined. The *how* and *when* are always difficult to predetermine in any exact manner. Broadly, it was decided that the *how* should be in a manner similar to conventional commercial operation, that is, the corporation wished to build a plant with its own funds and to produce material preferably for the open market if the demand appeared sufficiently established. But again, keeping in mind the possibility of technological obsolescence, the corporation wanted to be reasonably certain of an outlet for production for a period of time. It also wanted a minimum of government red tape such as permits and security regulations. Equity was an important consideration. The Nuclear Energy Department gave thought to an offer of consulting and process design services. In fact it did design for Vitro a heavy water plant for India, but later withdrew from such work because it offered no promise for equity.

The *when* occurred with the announcement by the Atomic Energy Commission of requests for bids for the production of zirconium, made in October, 1956. A careful reappraisal of the firm's position was made and it looked promising.

The demand for zirconium appeared strong. In the immediate future the market was expected to be supported by the Navy's program for construction of atomic powered ships. This fact was convincing enough that a sizable market would develop in commercial reactors within a few years and that a demand for commercial grade (hafnium containing) zirconium in corrosion resistant process equipment could be developed.

A.E.C. Provides Opportunity

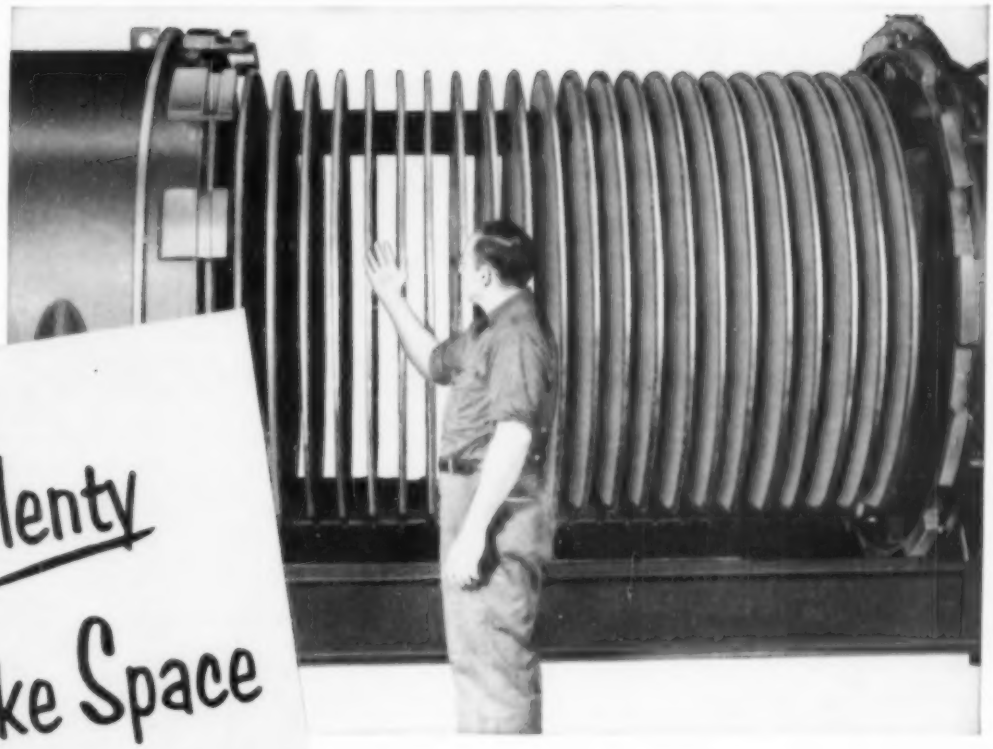
The A.E.C. request was for a company to build its own facilities and to bid on the basis of a price for each unit of product. There was only one commercial producer of zirconium, the Carborundum Company. The government facilities at Albany, Oregon, were to be reactivated but the Commission indicated that its operation would cease as soon as there were ample supplies of zirconium from commercial producers. It further indicated its plans to cease contracting for zirconium when supply and demand were in sufficient balance. Thus, it appeared that in the not too distant future conventional business practices would prevail.

The operation was not to be classified and subject to A.E.C. security regulations. The extraction process used in the government facility and at Carborundum was classified but the process developed at Cambridge is not. However, the firm does have some proprietary know-how and the process is confidential from a company standpoint. Thus, the management concluded that with the process know-how and the managerial and technical manpower, the project could be

Considering Entering the Nuclear Energy Field?

The author of the accompanying article has this advice to offer:

- **Determine where in the field of nuclear energy the technical, managerial, and financial resources of your company can be best brought to bear.** To some companies the direction may be obvious; to others it may entail a careful and detailed study. Don't expect to find a perfect opportunity. The important thing is to select an area, or what is just as important—stay out if you cannot find sufficient background in your organization and you are not prepared to build this background.
- **Initiate a research and development program where you can build a technical and, at least, a potential managerial staff and can contribute to the progress in nuclear developments.** If there is anything certain about this business, it is that the A.E.C. or industrial companies are not going to contract with a company to do work in an area in which the company does not have a high degree of competence and it is hard to see how a company can meet this requirement unless it is active in the field.
- **Undertake this program now.** Atomic energy has not truly reached profitable commercial operation in the sense of producing electrical energy at competitive prices, but it does not take a great deal of imagination and vision to see that it will some day in at least certain areas of the world, and in time, probably in all areas. The problems of producing electricity competitively, however, are reasonably well defined. Ten or more reactor designs have been studied in some detail and commercial plants are being built on the basis of five of these. This work has, and continues, to define the detail problems of construction, operation, and control among others. This is vastly different from the situation two years ago or even one year ago. A company which helps solve these problems stands a good chance of participating commercially in the development of the industry. Many companies are already in the field. Certainly if you enter now you will not violate the old business adage of "not the first to enter nor the last to leave," and it is reasonably certain that the companies which are to play an important part in the nuclear energy field are those which have already or are soon to enter the field.



Sparkler Model MCR filter showing generous cake space between plates for longer cycles.

Plenty Cake Space between plates

SPARKLER MODEL MCR FILTER

The total throughput (or cycle) of any filtering operation is largely dependent upon the amount of filter cake space available. Therefore, Sparkler has provided amply for this, to allow continuous operation far longer than is possible in filters where plates are spaced close together simply to increase plate area in a given size tank. Cake space is as important as plate area for effective filter capacity.

This large cake capacity is of particular importance for economical operation in heavy duty filtering.

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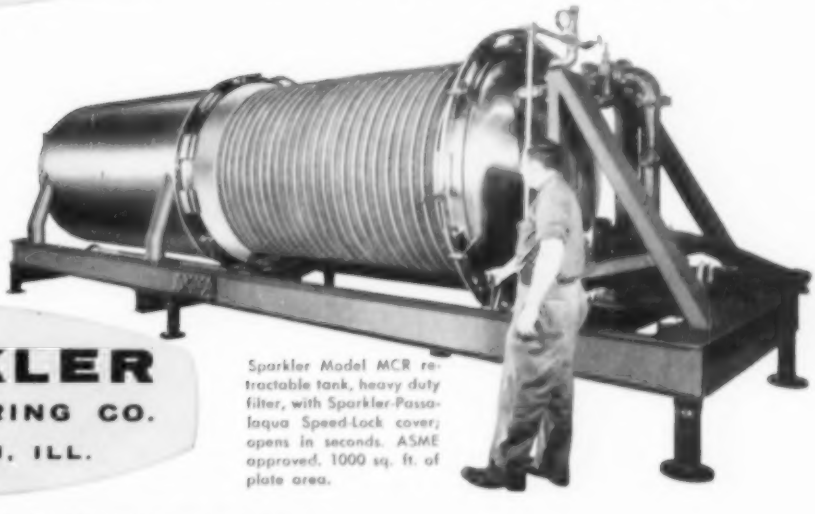

Sparkler Model MCR retractable tank, heavy duty filter, with Sparkler-Passa-laqua Speed-Lock cover; opens in seconds. ASME approved. 1000 sq. ft. of plate area.

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WHAT OTHER CHEMICAL COMPANIES ARE DOING IN THE NUCLEAR FIELD AND WHY

CEP's exclusive roundup of process industry firms in nuclear field gets answers to basic questions:

- *What business are you getting in the nuclear field?*
- *How does this business fit into your particular operation?*

• **Olin Mathieson**—"Our Nuclear Fuel Division produces fuel elements and reactor cores. Our interests in this field are a logical marriage between our traditional activities in metallurgy and chemistry, and our interest in the newest forms of energy for propulsion date from 1939 when we began our pioneering work in the field of high-energy chemical fuels."—M. F. Meissner, vice president and general manager, High Energy Fuels Organization.

• **Dow Chemical**—"We are devoting considerable attention to the use of radiation as a chemical processing tool . . . effects of beta and gamma rays on chemical reactions and processes are being studied. New products (not now available for publication) based on radiation processing are already at the stage of extensive development. We went into this field because our company is constantly seeking new and improved methods of carrying on chemical processing."—R. H. Boundy, vice president, research.

• **U. S. Industrial Chemicals** (National Distillers Corp.)—"As you know, we are now getting into zirconium production for AEC and private industry. We are participating in the private research reactor at Plainsboro, N. J. as part of our search for further nuclear materials and processes we can get into. Recently we formed, with Mallory-Sharon, Reactive Metals—a joint subsidiary to melt and fabricate zirconium. Our reasons—we had a sodium-based process for titanium, AEC wanted zirconium, so we adapted our process and produced zirconium. Our plant, on-stream soon, will have a larger capacity than announced, will produce 2 million pounds a year." R. E. Hulse, vice president, Chemical Activities, National Distillers.

• **DuPont**—Most of the company's nuclear work is contract work for AEC, done at the request of AEC. But they are building a $2 million radiation physics laboratory for long range research on the effects of radiation. A company spokesman said, "Our direct interest is not in the atomic power reactor field, but lies in the effect of radiation on chemical reactions and processes involved in chemical manufacture."

• **Mallinckrodt**—"We have had a Uranium Division working for AEC at their invitation ever since 1942. The Division is engaged in processing uranium. We have now set up a Special Metals Division to be separate from our AEC operations as a strictly commercial operation to produce reactor grade uranium oxide as a raw material for fabricators of fuel elements. (See **CEP**, January 1957.) We had the experience and know-how and felt there was a sufficient market now to develop our own process."

• **National Lead Co.**—Company achievements in the nuclear field have ranged over a broad area, including production of shielding materials, operation of a uranium processing mill, development of uranium concentration processes, production of uranium and thorium chemicals and metals, and the fabrication of fuel elements. The company's long experience with metals and minerals, together with its long-time production of chemical products, made nuclear work logical.

• **Great Lakes Carbon Corp.**—"We're in the atomic energy field to produce and sell nuclear-grade graphite. We have joined in the formation of Anglo-Great Lakes Corp. Ltd. and expect to have a graphite plant on stream at Newcastle, England by mid 1958, with priority given to atomic energy requirements."—R. B. Wittenberg, vice president and general manager, Electrode Division.

• **Davison Chemical Co.** (W. R. Grace & Co.)—"Thoria, the oxide form of thorium, is produced in Davison's $2 million rare earths processing plant. Operating under a government contract through 1957, the new plant processes some 20 tons of monazite sand a day."

• **Vitro Corp.**—Vitro is a company in the nuclear field "across the board." It operates extensively throughout the industry. Using uranium since 1926, in atomic energy since the early days of the Manhattan Project, Vitro today is in the design and construction of nuclear facilities, in the mining and processing of uranium and other metals important to nuclear work, and is in chemical reprocessing of nuclear fuel.

• **Sylvania-Corning Nuclear Corp.**—"Formed by Sylvania and Corning Glass, our new company is building a multi-million dollar research facility at Andover, Mass. and will soon select the site for a giant nuclear fuel reprocessing plant, also in New England. We decided 10 years ago to get into the nuclear field, drew on our metallurgical experience, established an Atomic Energy Division, have now formed the joint company with Corning."—D. G. Mitchell, Chairman of the Board and President, Sylvania Electric Products.

• **Union Carbide**—Had one of the earliest major roles in the nuclear program, both civilian and military. For AEC, the company ranged from mining through refining, from reactor design through fuel reprocessing (including development of first process for hafnium-free zirconium). Within the last two years the company formed Union Carbide Nuclear Co. to coordinate its varied nuclear interests. Studying the entire picture, one thing is certain—the company's role will represent a wedding of the nuclear radiation and chemical processing fields.

• **Carborundum**—"Initial producer of zirconium and hafnium for AEC, we are still in it and expanding, with considerable zirconium available for private use. Because of our long experience, the bulk of our nuclear work has developed around silicon carbide, aluminum oxide, and boron carbide. Latest work is on ceramic fuel elements."—D. G. Sturges, manager, New Products Branch, Research and Development Division.

financed. The go-ahead signal was therefore given.

Details of Negotiation

Those who wish to have an idea of what is involved in successfully negotiating a government contract of this type may be interested in a few details. The A.E.C. allowed three months for the interested companies to prepare bids. It asked for bids at five levels of production for two different periods of time (or ten alternatives) and for each of these cases requested a unit price per pound. This entailed making a capital cost and operating cost estimates at five levels of production and calculating economic projections over two periods of time—three years and five years. The bid was prepared and submitted February 1, 1956. The A.E.C. received requests for information on their request for bids from about 100 companies, ten formal bids were submitted, and three contracts were awarded.

In selecting the recipients of the contracts, the A.E.C. moved rapidly, extremely rapidly. One day after the bid was submitted, it invited members of the subject firm's management in Chicago for a conference the following day, incidentally a Saturday. In the ensuing three months the process design was reviewed in detail by a technical team from the A.E.C. and the new and novel features of the process were demonstrated by pilot plant operations. At the end of that time, a contract was signed which included such features as cancellation provisions, both by default and at the convenience of the government, patent and price clauses, and a price redetermination provision.

Negotiations were completed with the highest respect for the A.E.C., which demonstrated sound business judgment, technical competence, and justice at all times. After signing the contract the course was clear—to build a five million dollar plant within fourteen months, raise the money for financing the project, and find the managerial and technical personnel to staff the plant. In the several months since the contract award, the key positions of the new organization have been staffed with top men in each category. The entire process design is complete, the equipment has been ordered, and construction is well under way. Shakedown operations are scheduled for this spring. This, then is the *where*, *how*, and *when* of NRC's zirconium project.

Presented at A.I.Ch.E. meeting, Boston, Massachusetts.

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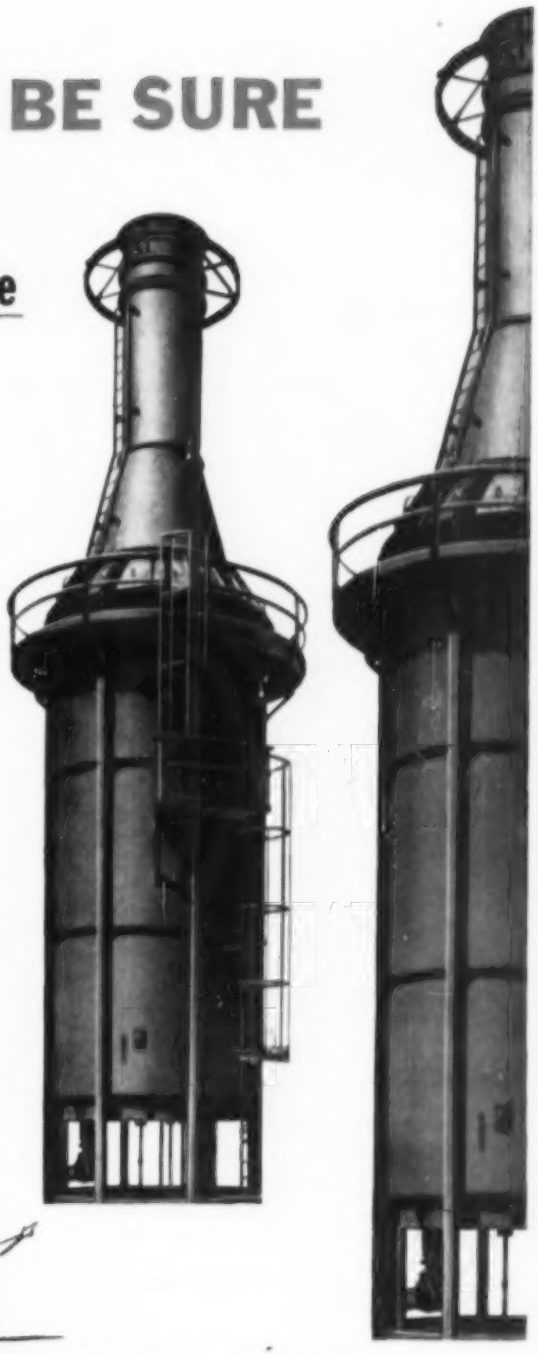

Whenever *all* the specifications and *all* the operating requirements are applied to direct-fired furnace design, you can be sure PETROCHEM-ISOFLOW FURNACES will be found most economically desirable, by any comparison.

In making comparisons it is essential to take these factors into consideration:

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4—Maximum tube wall temperature, radiant or convection.
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8—Design to provide: structural column supports—Ladders—Platforms—Tube Removal facilities, etc.
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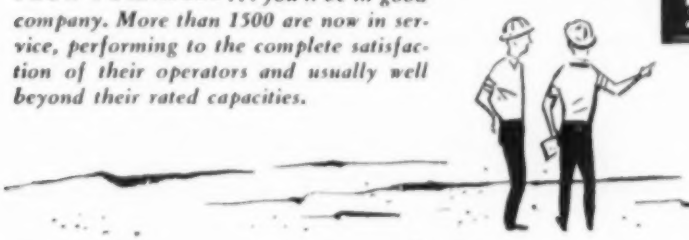

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Letters to the editor

Hot Carbonate Process Wins Advocate

I found your article on "CO_2 Absorption," page 433 of October, 1956 issue, very helpful.

D. L. Stockbridge, Jr.
Savannah, Georgia

What's in a Title!

On page 97 of the December issue of *CEP* under the "People" heading, it is reported that "Edward A. O'Neal, Jr., previously with the U. S. Defense Corp. at St. Louis, is appointed assistant to the president of Chemstrand Corp."

Unfortunately that isn't quite correct. Mr. O'Neal is the president of the Chemstrand Corporation, not assistant to the president.

Since Mr. O'Neal is widely known in the chemical industry, coming to Chemstrand last May from a post as vice president and director of Monsanto Chemical Company, you may wish to correct this item in your next issue.

Robert D. Holloway
Public Relations Department
The Chemstrand Corporation
Decatur, Alabama

Marginal notes

Experimental Power and Test Reactors—TID-4562.

A.E.C. Technical Information Service (November, 1956). Introduction by W. K. Davis, Director, Div. Reactor Development, A.E.C. Free of charge from Technical Information Service Extension, P.O. Box 62, Oak Ridge, Tennessee.

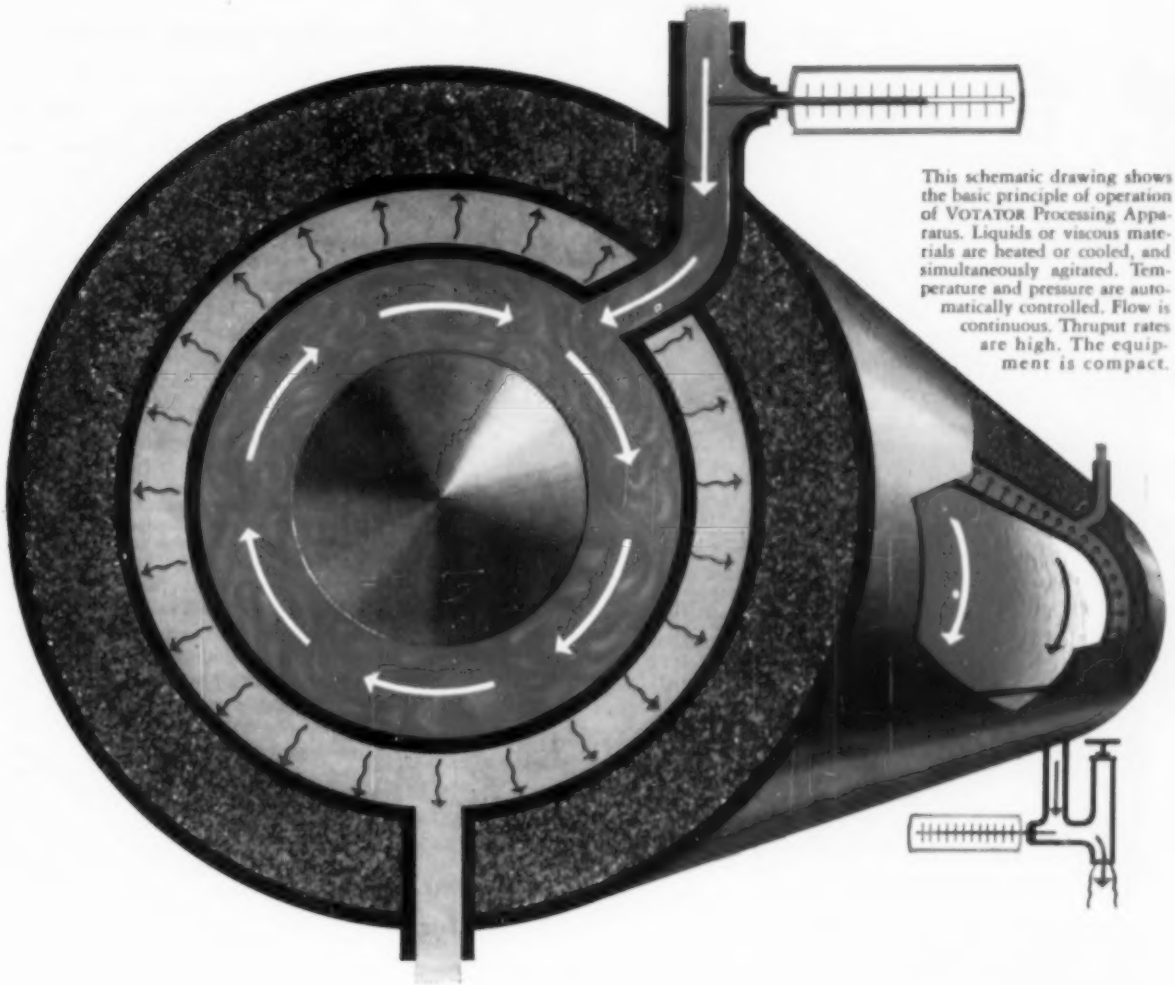
The Technical Information Service of the A.E.C. has issued a compact survey of technical information on the major aspects of the experimental reactor program of the Commission. Included are significant engineering data, cut-away views of the reactors, equipment dimensions and specifications, flow diagrams, and many photos of various construction phases.

Reactors described in the brochure are the following:

Experimental Reactors

Shippingport Pressurized Water Reactor (P.W.R.)
Experimental Boiling Water Reactor (E.B.W.R.)
Sodium Reactor Experiment (S.R.E)
Experimental Breeder Reactor No. 1 (E.B.R-1)
Experimental Breeder Reactor No. 2 (E.B.R-2)
Homogeneous Reactor Experiment No. 1 (H.R.E-1)
Homogeneous Reactor Experiment No. 2 (H.R.E.-2)
Organic Moderated Reactor Experiment (O.M.R.E.)

(Continued on page 28)



This schematic drawing shows the basic principle of operation of VOTATOR Processing Apparatus. Liquids or viscous materials are heated or cooled, and simultaneously agitated. Temperature and pressure are automatically controlled. Flow is continuous. Thruput rates are high. The equipment is compact.

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A host of chemical and food products are being made better and at lower cost with VOTATOR* Continuous Processing Apparatus. This heat-transfer equipment agitates and simultaneously heats or cools liquid or viscous materials. Its output rate is six to ten times that of conventional batch methods. The system is completely enclosed for absolute product cleanliness. Flow is continuous, automatically controlled for highest quality at all times.

Girdler engineers will gladly analyze your processing to show you specifically how VOTATOR Processing Apparatus can improve your product and lower your costs. Call us today.

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Marginal notes

(*Continued from page 26*)

Liquid Metal Fuel Reactor Experiment (L.M.F.R.E.)
Los Alamos Molten Plutonium Reactor Experiment (LAMPRE)

Test Reactors

Materials Testing Reactor (M.T.R.)
Engineering Test Reactor (E.T.R.)
Special Power Excursion Reactor Tests (S.P.E.R.T.)

The brochure is an invaluable reference manual for any engineer interested in following the progress of our nuclear experimental program.

—*W.H.*

Standard Testing Procedure for Heat Exchangers.

Section 2. Shell-and-Tube-Type Condensers, 16 p. Standard Testing Procedure for Absorbers, 21 p. A.I.Ch.E. Committee on Equipment Testing Procedures. Available from Secretary's Office at $1.00 each.

The contents of the pamphlet on procedure for heat exchangers covers the following: purpose and scope; definitions and description of terms; establishment of test conditions; methods of measurement; test procedure; special procedure for acceptance tests; computation of results; and interpretation of results. For absorbers the study includes the purpose and scope; definitions and descriptions of terms; test conditions and data; methods of measurement; test procedure; computation of results; interpretation of results; and notation. Both procedures were approved by Council of A.I.Ch.E.

Elementary Nuclear Theory. Hans A. Bethe and Philip Morrison.

John Wiley & Sons, New York (1956), 264 pages, $6.25.

Reviewed by Alexander Sesonske, Associate Professor, Chemical Engineering, Purdue University, Lafayette, Indiana.

This volume represents a welcome revision of a definitive book on nuclear forces and other nuclear physics topics. The material will be of interest chiefly to those chemical engineers having nuclear specialization who want to find out more about the basic physics pertinent to nuclear reactions.

The first part, consisting of seven short chapters, is devoted to rather elementary descriptive material on nuclei. Although this section is readable, a more systematic introduction to the subject is obtainable in standard texts. The next ten chapters are devoted to the discussion of the quantitative theory of nuclear forces. Much interesting material of a semidescriptive nature is included. Although most chemical engineers without advanced

(*Continued on page 30*)

Marginal notes

(*Continued from page 28*)

training in nuclear physics would hardly regard the treatment as elementary, many broad principles are presented in such a way that they can be understood by the superficial reader. Several chapters are devoted to nuclear structure, nuclear reactions, and cross sections.

The topics approach is used throughout the volume. Only half the topics would probably be of interest to an engineer with nuclear specialization. This half, however, is good, and makes the volume a useful source book.

Polyesters and Their Applications.

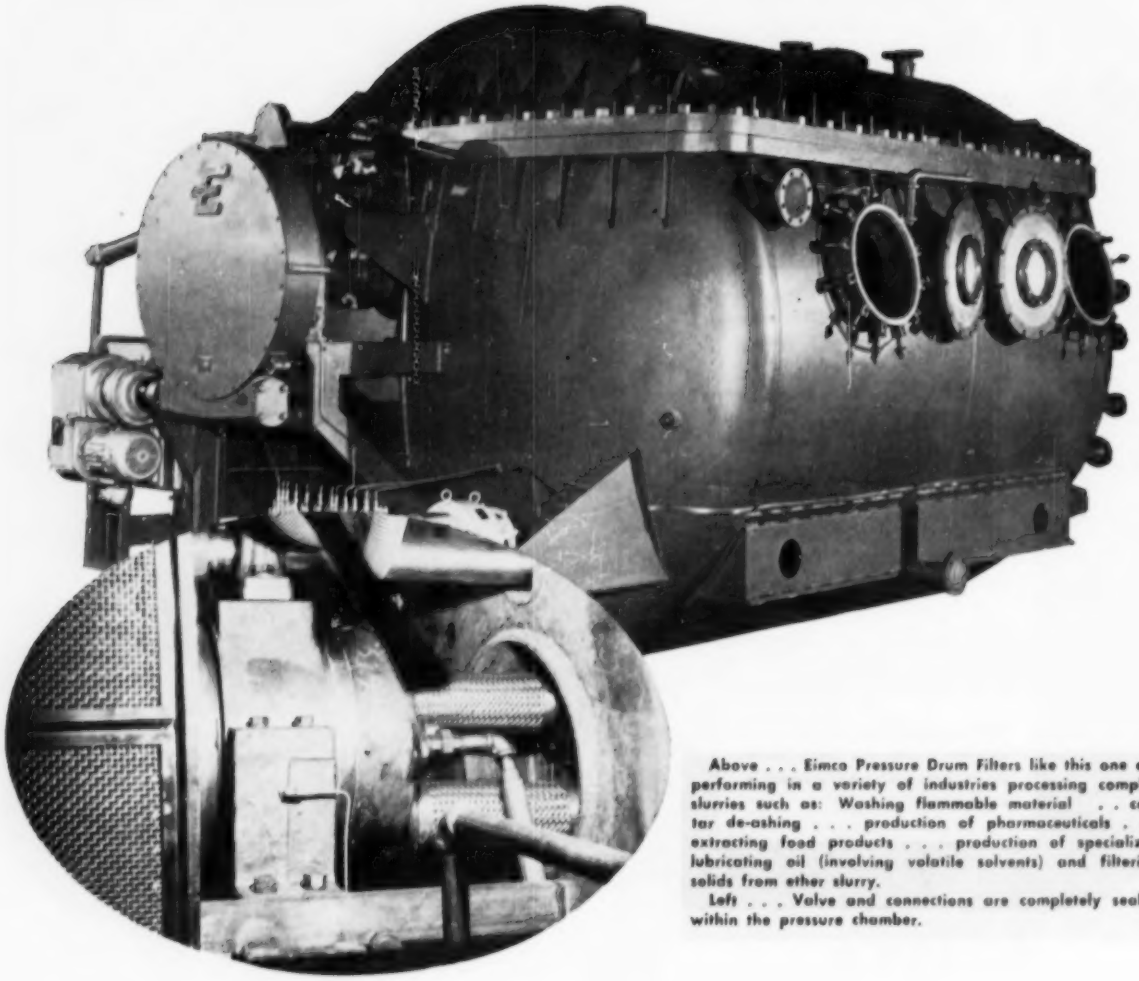
Bjorksten Research Laboratories, Inc., Madison, Wisconsin. Reinhold Publishing Corporation, New York (1956), 618 p., $10.00.

Reviewed by John F. Palmer, Jr., Group Leader, Organic Chemicals Division, Monsanto Chemical Company, St. Louis, Missouri.

Both research chemists and chemical engineers should find this book a welcome addition to their personal technical libraries. Here is a reference book on polyesters and their innumerable applications—not a text book. Although the format does not suggest it, detailed examination reveals that this book is merely an excellent annotated bibliography extending through June 1, 1954. There are more than 3,000 references, including patents, books, articles, and manufacturer's publications, which have been classified according to their principal topics.

The procedure of collecting all the references in a classified appendix has resulted in the presentation of an easy-reading text. The basic text includes a brief section on the theory of high polymers with particular respect to polyesters, touches lightly on saturated polyesters, methods of testing, and health hazards. By far the major portion of the text is devoted to unsaturated polyesters and covers such phases as raw materials, resin manufacture, catalysts and inhibition, fillers and reinforcement, shaping, finishing, commercial resins, and so on. Combining all this information into one volume has necessitated extreme brevity in the text material.

The book has a subject index and an index of authors, companies, and organizations. Drawings and graphs, though not numerous, are clear and concise. Tabular data used to illustrate points brought out in the text appear to be well chosen and typical of conditions normally being met.



Above . . . Eimco Pressure Drum Filters like this one are performing in a variety of industries processing complex slurries such as: Washing flammable material . . coal tar de-ashing . . . production of pharmaceuticals . . . extracting food products . . . production of specialized lubricating oil (involving volatile solvents) and filtering solids from ether slurry.

Left . . . Valve and connections are completely sealed within the pressure chamber.

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where correct application of Eimco Pressure Filters will get you appreciable advantages:

(1) Where vapor pressure of the liquid at the filter feed temperature is too high to permit the efficient use of vacuum . . . **(2)** Where liquid viscosity is high (generally 100 centipoises or more) or solid particle size is very small, requiring a driving force greater than one atmosphere to get economic filtration rates . . **(3)** Where large labor savings and lower operating costs justify higher initial expenses . . . **(4)** Where employment of a valuable or high temperature gas for the production of a dried cake product is feasible . . . **(5)** Where filtration of saturated solutions results in excessive crystallization with a reduction in temperature or pressure.

Whether you are pre-planning for filter installations to handle new processes or are seeking to improve present operations . . . these are some of the general conditions that justify an investigation into **Eimco Continuous Pressure Filter Equipment.**

Submit your problem to the Eimco Research and Development Center, Palatine, Illinois. They have complete facilities to test your slurry on all types of filtration equipment to assist you in selection of a proper unit.

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Whatever your filtration problem, let Eimco's competent research facilities go to work for you. Write today!

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New Engineers' Joint Council Salary Survey Reports on . . .

WHAT ENGINEERS ARE PAID

Second EJC survey, based on 107,832 engineering graduates questioned in 1956, shows actual earnings of engineers in industry, government, and education related to number of years since receipt of first degree. As interpreted by Rutgers salary expert E. B. Peck, the survey shows median salary curve for lifetime pay of engineers begins at $5,300 and ends at $11,000. Beginning salaries have kept pace with wages and cost of living, but experienced engineers' pay has lagged far behind.

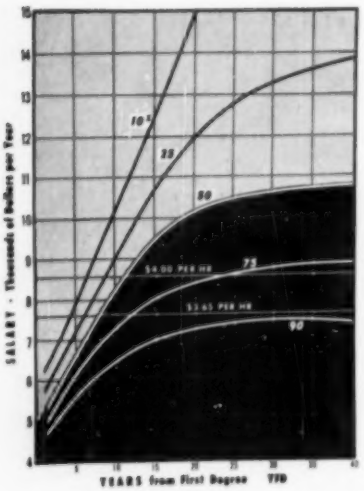


Fig. 1.

"There is much talk about other incentives besides pay, and they are important. But the hub is pay. Other incentives have a hollow ring when pay is not right." Ex-industry engineer and now Rutgers professor E. B. Peck thus succinctly analyzed EJC's survey of what engineers earn.

Realizing the need for a comprehensive study to evaluate the earning potential and general salary status of the engineer, EJC undertook its first survey of this type in 1953. The present survey, representing data gathered up to December 1956, reduces the information to a series of charts and tables based on a simple questionnaire which requested only the employee's earnings classified by year of first degree, and the current starting salary rate. The report contains the facts on 107,832 engineering graduates employed in industry, government, and engineering education. This sample represents 17.5% of the total estimated engineering graduate population. The returns from industry are classified in accordance with the Standard Industrial Classification Manual, but no attempt was made to obtain salary information by field of specialization, such as chemical or civil engineer.*

Peck, giving a statistical analysis and interpretation of EJC's just-released report during a panel session at [illegible] General Assembly† emphasized that the main salary problem over the past 18 years has been "telescoping salaries," which means simply that "engineers' salaries do not grow with experience as much as they used to." In short, while beginners' salaries have risen since 1939 as much as wages (250% for beginners, 208% for wages, see Table 2), experienced engineers' salaries have not kept pace (only 91% more than 1939 for engineers with 20-24 years experience). These figures underline what has become the engineer's prime complaint—too low a differential between salaries and wages, and between beginners and experienced men. (See report on NICB survey in January *CEP*, and article by H. L. Rusch in same issue.)

Engineers' Salaries—1956

Figure 1 is the graph of minimum salaries for various percentile groups of engineers in 1956 (from EJC's survey). They are averages for all industry employing engineers. As Peck says, "All industries do not pay equally well. Chemical engineers are paid better than civil and sanitary engineers. Research and development pays better than production engineering. Industry pays better than government or education."

Table 1 shows engineers' salaries at various experience levels and as they have changed since 1939. In the first column average weekly wages in manufacturing are shown. Comparison of salaries and wages is difficult, since factors such as actual number of hours worked, type of industry and job, lay-offs, all affect the actual earnings of the wage worker. Far better evidence of the problem of engineer's compensation is the comparison of percentage changes in pay rates since 1939 (Table 2).

In a period when gross national product increased more than four-fold, cost-of-living index doubled, and wage

(*Continued on page 38*)

Table 1.—Salaries and Wages

Year	Average weekly wages [1]	Engineers' Salaries at Various Experience Levels [2] Less than one year	9-11 Years	20-24 Years	35-39 Years
1939	$0.633	$127	$259	$435	$550
1946	1.086	232	401	515	629
1952	1.670	356	549	670	670
1956	1.950	443	670	852	905

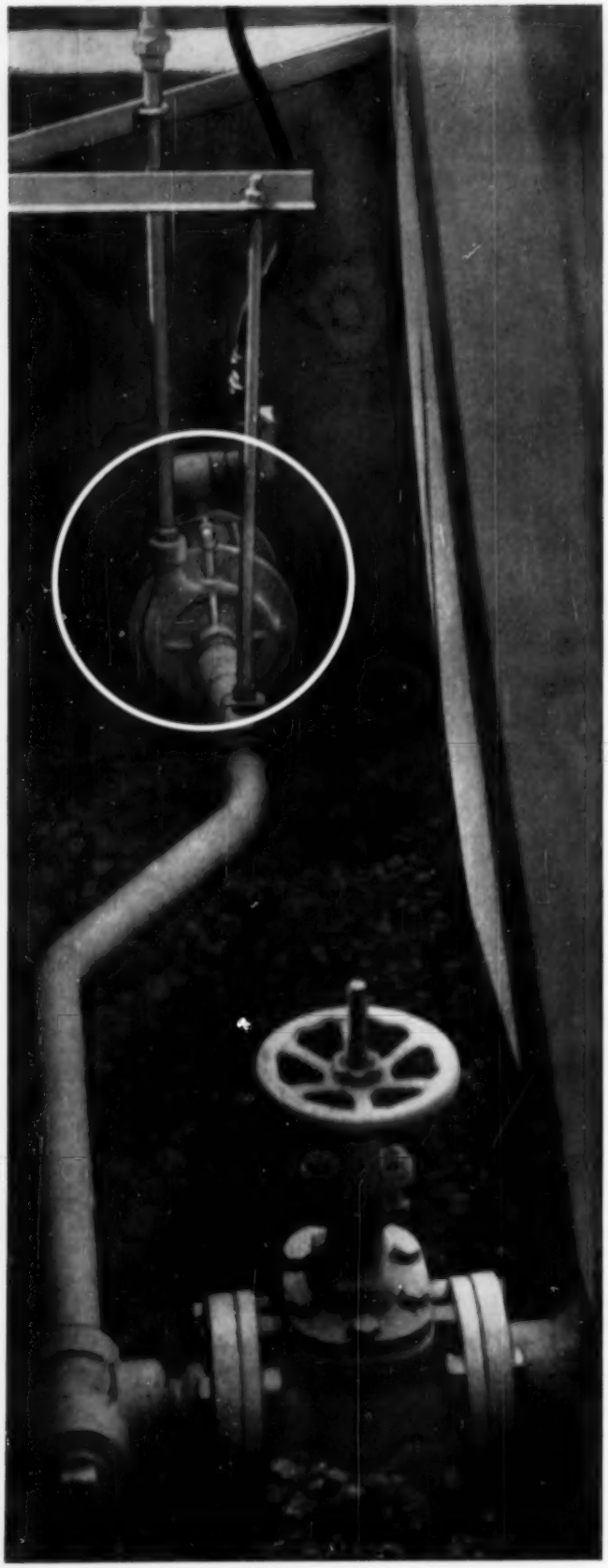
[1] Average weekly wages in manufacturing (dollars per hour).
[2] Salaries in industry. Experience measured as years from bachelors degree (dollars per month).

Table 2.—Percentage Increases for Significant Periods

	1939-46 %	1946-52 %	1952-56 %	1939-56 %
Productivity	89	50	14	223
Consumers' Index	41	36	3	97
Median Engineers' Pay at Experience of:				
Less than one year	83	54	24	250
9-11 years	55	37	22	159
20-24 years	18	30	26	91
35-39 years	14	7	35	65
Wages	72	54	17	208

* The full report, "Professional Income of Engineers—1956," is available from Engineers' Joint Council, 29 West 39 St., N.Y.C., price $1.50.

† Held Jan. 17-18 in New York's Hotel Statler, the panel consisted of: D. S. Bridgman, former director of College Relations, A.T. & T., chmn.; E. B. Peck, Rutgers U.; D. P. Kratz, asst. to the president, Cal. Research Corp.; and F. Leamer, personnel director, Bell Telephone Laboratories, Inc.



Chempump saves $1000 a year in maintenance costs

handling sulfuric acid at laminates plant of Panelyte Division, St. Regis Paper Co.

This *Chempump* is part of the phenol recovery process at the Trenton, N. J. plant of St. Regis Paper Company's Panelyte Division. The pump operates intermittently for about ten minutes, three times during each shift of a three-shift day. Since its installation, in July 1955, it has been continually on the job, moving about a thousand pounds of 66° Baumé sulfuric acid every day. No maintenance has been performed on the pump since it was installed—not even a bearing inspection. The plant's maintenance superintendent states that this *Chempump* has saved more than $1000 in maintenance expense during its first year of operation.

Originally, a stuffing box pump was used in this service. Leakage corroded the pump frame and base plate to such an extent that the pump had to be replaced three times. Acid which leaked from the stuffing box also ate away the concrete mounting block.

Leakage problems ended with installation of a *Chempump*. *Chempump can't* leak—in or out—because it has no seals, no stuffing box, no packing. External lubrication is never needed, because the bearings are constantly lubricated by the pumped fluid itself.

Chempump can economically solve the problem of problem fluids in your own plant. For details, write to Chempump Corporation, 1300 East Mermaid Lane, Philadelphia 18, Pa. Engineering representatives in over 30 principal cities in the United States and Canada.

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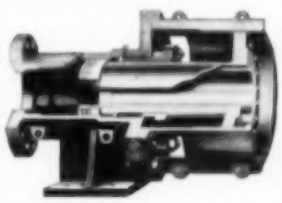
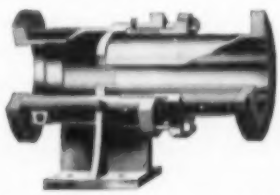
1. **LESS HEAT LOSS.** A 12-inch line 1000 feet long, carrying steam at 200 lbs. and 550 F, will lose 16% more heat if bends are used instead of ADSCO Expansion Joints.
2. **LESS PRESSURE DROP.** The same line will have a 28% greater pressure drop with bends than with ADSCO Expansion Joints.
3. **LESS SPACE.** One pipe bend requires 100 to 300 sq. ft. of valuable space. An ADSCO Expansion Joint requires little or no extra space.

And, in addition, ADSCO Expansion Joints cost less. Used to absorb 4 inches of expansion per 150 feet of 12-inch pipe, an expansion bend, or loop, will cost 50% to 100% more than an ADSCO Expansion Joint. Similar savings can be obtained for other sizes of pipe and for different conditions.

Corruflex Packless Expansion Joint. Requires no maintenance.



Piston-Ring Expansion Joint. Can be unpacked at full operating pressure.



Internally Guided Expansion Joint. Traverses of 4", 8", and 12" per slip.

If you are planning construction of a pipe line, by all means investigate ADSCO Joints. If you already use bends, ADSCO can replace them with joints which will perform better and will still save money.

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WHAT ENGINEERS ARE PAID

(Continued from page 34)

rates tripled, the salaries of experienced engineers increased even less than the cost of living. In the 1939-1956 period the incentive factor of increased pay with experience was reduced about half. Peck, in pointing particularly to the Civil Service, said: "One wonders how much the Civil Service, in holding down salaries in the higher classified jobs, yielded in qualifications and performance of personnel." This comment could just as well apply to the same phenomenon in industry. If salaries had increased by the same factor as wages since 1939, Peck showed, starting salaries would be a little lower than now, but the median would rise to $16,000 per year at mid-career instead of the $10,000 now, and would end at about $20,000 instead of the present $11,000.

A Pattern for Salary Administration

A salary survey, Peck emphasized, can be used as a guide in salary administration—but only as a supplement to good job evaluation and merit rating. From the EJC survey, Peck has developed a formula for salary determination policy. "At any merit level, the annual rate of salary increase is proportional to the salary, multiplied by the amount of money left for salary increases for the rest of the career." This formula is based on examining curves derived from Table 1. These salary curves suggest that each curve is aimed at a goal which is a potential for the employee. But this does not mean that potential cannot be changed. Periodic merit ratings and performance reviews change these potentials.

In mathematics the formula developed by Peck is:

$$ds/dt - kS(A - S)$$

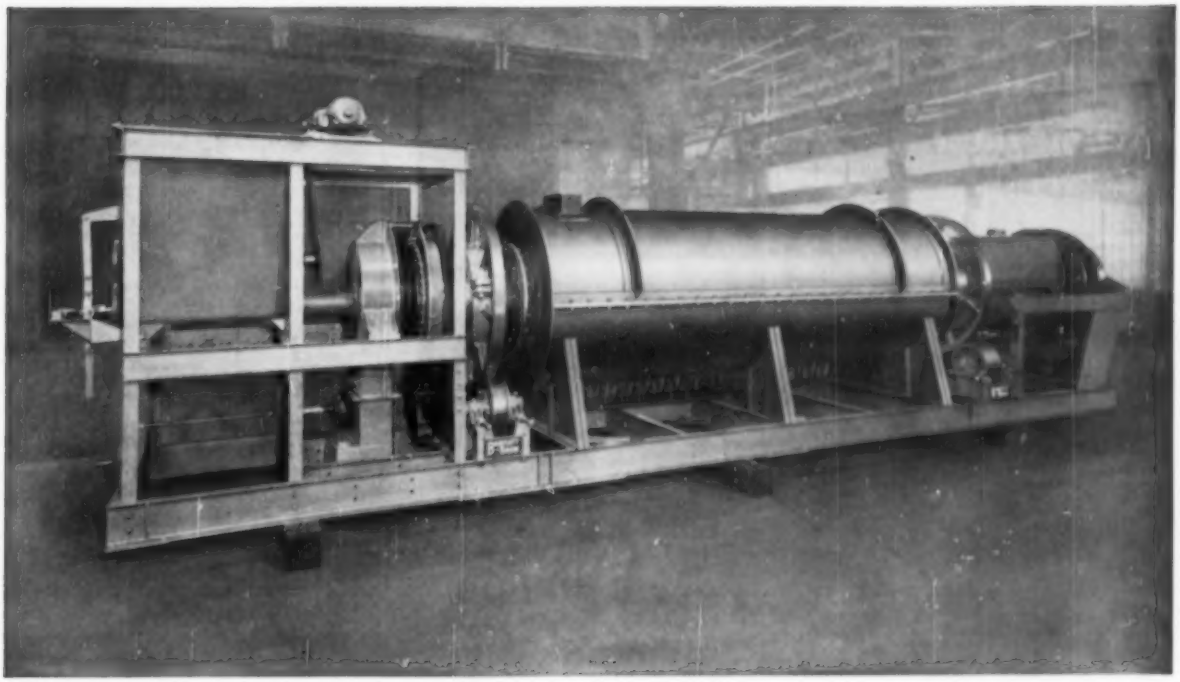
where S is the salary, t is the experience in years from first degree, k is a constant computed for each curve from the end condition, and A is the potential salary for each curve.

But having the formula and the curves is not useful without practical and accurate methods of job evaluation and merit rating.

Position Evaluation

The engineer, panelist Krotz pointed out, does not usually work as an individual in the manner of a doctor, but as part of a larger group or team: "In considering this problem of proper pay

(Continued on page 40)



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. . . permits materials to be processed continuously at temperatures from 900° F to 2100° F in a reducing, oxidizing or neutral atmosphere, cooled, and discharged at 200° F or lower.

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WHAT ENGINEERS ARE PAID

(Continued from page 38)

for engineers and scientists, one of the first conclusions management usually reaches is that they have need for some kind of yardstick which permits them to relate the value of one man's efforts in comparison with those of other employees."

One of these yardsticks is position evaluation—in essence, the setting-up of salary scales according to the true value of the position held by an engineer in the company, setting a value for the position itself rather than for the engineer in it. Position evaluation involves three steps: 1) analysis, in which a full and complete description of the job is made by actually studying it; 2) measurement, where a procedure for measuring the actual value of the position to the company is developed—one good tool here is the use of a "personnel committee" composed of men with long experience in supervisory positions in the company; 3) audit, where the results of the first two steps are checked and cross-checked within the company and also against outside companies with comparable jobs to help determine the actual "price" for the positions being evaluated.

Merit Rating

The factor of "personal performance" leads directly to panelist and personnel director Leamer's presentation of merit rating systems. "Most unions would prefer to have their members rated strictly on the basis of seniority without any merit consideration. They do not trust the ratings of management people. Technically trained people, however, generally prefer to have salary progress and promotion based on individual contribution or merit." But merit ratings are necessarily open to defects based mainly on subjective human problems that result in "rater bias" of one form or another. Many systems and modifications have been developed for the main purpose of getting rid of this conscious or unconscious rater bias. But it still remains true, Leamer admitted, that there is no one best method for all merit rating situations. Each must be tailored to fit the circumstances. "Merit rating today is a useful tool for industry when, and only when, it is used with full awareness on the part of all concerned of its limitations . . . The best possible condition is satisfied when each rater has observed at close range, over a long period of time, the performance of each individual rated."

ADVERTISEMENT—*This entire page is a paid advertisement* *Prepared by U. S. Industrial Chemicals Co.*

U.S.I. CHEMICAL NEWS

Feb. ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1957

Ludlow Succeeds Keane as Director of U.S.I. Sales

Alden R. Ludlow, Jr. has been named Director of Sales for U.S.I., succeeding Lee A. Keane who has just retired. Mr. Ludlow has been Manager of Alcohol Sales for the past ten years.

He will now have full charge of the nationwide U.S.I. sales organization, responsible for marketing all of the company's product lines.

Alcohol Reduces Friction In Aluminum Grinding, Says Russian Report

A 44% decrease in friction when grinding aluminum with the aid of ethyl alcohol, compared with results obtained in air, is reported by a Russian experimenter at the Siberian Physico-Technical Institute. At the same time it was noted that abraded mass decreases 34% and specific energy 14% compared with results obtained in air.

The investigation was conducted to learn more about how liquids actually aid in the cutting and grinding of metals. Some Russian research men have claimed that these liquids loosen the metal molecules at the working surface. Others have deduced that they make the metal more brittle.

This investigator has concluded, in the case of grinding aluminum with the aid of ethyl alcohol, that the liquid forms a buffer layer which decreases the pressure of the load and so decreases the force of friction.

Have You a New Product To Tell the World About?

Make it routine to send your publicity releases on new products and developments to the Editor of U.S.I. Chemical News, often called the "Front Page of the Chemical Process Industries." The issue you are reading right now will be printed in over 250,000 copies of the leading publications serving the chemical and related fields. The Technical Developments column alone will probably produce over 600 inquiries, judging from the past average. You incur no charges or obligations by sending us your new product releases. The material will be judged and used solely on the basis of newsworthiness and space limitations. And of course we cannot guarantee that your item will definitely appear because of these considerations.

Address the Editor, *U.S.I. Chemical News*, U.S. Industrial Chemicals Co., Division of National Distillers Products Corporation, 99 Park Ave., New York 16, N. Y.

Medium-Density Polyethylene Is Now Available from U.S.I.

Expansion to 100 Million Pounds per Year Will Place Plant Among World's Largest; Output to Include Conventional and Higher Density Resins

New production techniques are yielding higher density polyethylene resins at the Tuscola, Illinois plant of U.S.I.'s subsidiary, National Petro-Chemicals Corporation. These materials are designed for use where the conventional (low-density) resins do not quite meet requirements for certain applications. They have greater stiffness and tensile strength than the conventional grades, and a higher softening point. Low temperature brittleness and vapor permeability characteristics also improve with increasing density. On the other hand, as density gets higher, film brittleness tends to increase while tear and impact strengths tend to decrease.

The MCA Technical Data Book for Plastics identifies polyethylene resins according to densities in the following manner:

LOW DENSITY	— 0.912 to 0.925
MEDIUM DENSITY	— 0.926 to 0.941
HIGH DENSITY	— 0.942 to 0.965

Expansion Doubles Plant Size

Total resin capacity of the polyethylene unit will be 100 million pounds per year when present expansion is completed. This unit had a design capacity of 26 million pounds per year when it came onstream in February of 1955 but is currently operating at twice that output. The ethylene plant and the extraction, fractionation and power plants at the integrated Tuscola petrochemical facilities are also being enlarged to supply the polyethylene plant.

MORE

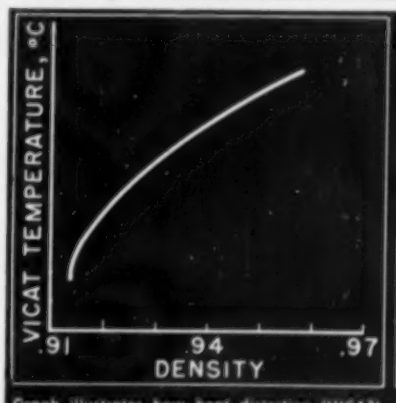
New Volume on Metallurgy Of Titanium Just Published

A 466-page reference book on "Titanium" has just been published as Volume 4 in a series on the "Metallurgy of Rarer Metals" by the British writing team of McQuillan and McQuillan. Comprehensive and highly readable, the volume combines both academic and industrial findings on titanium, covering its history and occurrence, recovery from ores, preparation, purification, properties and reactions.

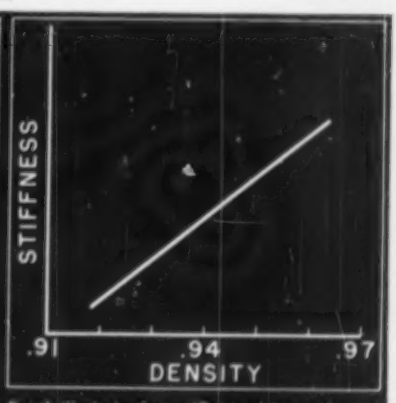
The larger part of the book is concerned with the properties of titanium and its alloys. One long chapter deals with fabrication and joining. Other sections cover physical properties, mechanical properties, heat-treating and mechanical properties of titanium-rich alloys, deformation mechanisms and textures, transformations in titanium and its alloys.

A chapter on the constitution of titanium alloys describes the problems which arise in studying these systems and goes into the determination of phase boundaries. Binary and ternary systems are discussed. A separate chapter is devoted to titanium metallography.

The important subject of titanium's reactions with gases is covered fully, with particular reference to oxygen, nitrogen and hydrogen. The behavior of titanium in aqueous solutions and in the presence of common corrosive agents is also included.



Graph illustrates how heat distortion (VICAT) temperature varies as density of polyethylene increases, molecular weight and molecular weight distribution remaining constant



Graph illustrates how stiffness varies as density of polyethylene increases, molecular weight and molecular weight distribution remaining constant.

Feb. ★ **U.S.I. CHEMICAL NEWS** ★ 1957

CONTINUED

Expansion

High Pressure Process Modified

By modifying high pressure techniques now employed at Tuscola for making conventional, low-density resins, the plant is also able to manufacture medium and high density materials in the same equipment. U.S.I. will concentrate, for the present, on producing medium-density polyethylenes by these modified techniques.

U.S.I. has been marketing conventional, low-density polyethylenes (0.92) under the trade name PETROTHENE® since February of 1955. In use, the PETROTHENES have shown an inherent superiority in certain properties such as stress crack resistance, processibility and uniformity. Field tests on the new medium-density resins, closely akin to the conventional grades, have indicated similar superiority. However, as density is increased, there is the possibility that these proven properties could vary. A great deal of work must be done to develop the best of all possible high-density resins, and so U.S.I. plans to move slowly on the production of these materials. The goal: to improve other properties without sacrificing superiority in those properties already proved.

Resins Can be Tailor-Made

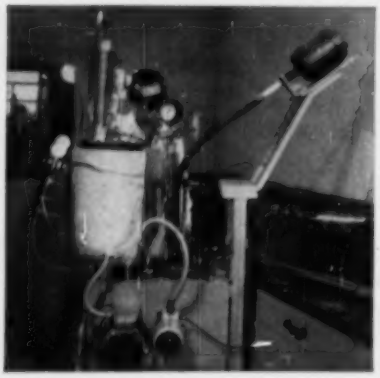
Flexibility of the production techniques now being employed at the Tuscola plant adds a new dimension to polyethylene's range of properties. This plant has been supplying plastics processors with polyethylene grades especially suited to particular processing conditions and end uses. Now with the ability to vary density, the plant can provide the same property variations as before—at new density levels. As a result, processors of polyethylene can obtain a tremendous variety of raw materials with a wide range of characteristics.

Methionine Counteracts Toxin in Plant Disease

The poisonous action of a naturally occurring antimetabolite of methionine which causes wildfire disease in tobacco plants can be overcome by methionine, according to a recently published report.

Some Grignard Reagents Can Now be Prepared by An Easy Sodium Route

An economical route has now been opened to the preparation of certain Grignard reagents difficult to obtain by direct reaction from chlorohydrocarbons. Recent studies at the U.S.I. Research Laboratories in Cincinnati have demonstrated that organomagnesium compounds may be prepared in hydrocarbon solvents from organosodium compounds and anhydrous magnesium chloride. The use of ethers may be avoided completely if desired. Organolithium compounds may be similarly prepared from organosodium compounds and anhydrous lithium chloride.



Sodium dispersions for preparation of organosodium compounds can be prepared in this package pilot plant unit, which is available on loan from U.S.I. Research Division.

These developments will be discussed in detail by Dr. John Nobis of the U.S.I. Research Division in a paper to be presented before the ACS Symposium on Metal-Organic Compounds this April. The paper, entitled "Use of Organosodium Compounds for Preparation of Other Carbon-Metal Bonds" will also describe reactions with the halides of boron, aluminum, silicon, titanium, tin and phosphorus, or in some cases, their alkoxides.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing the Editor, U.S.I. Chemical News.

New x-ray microscope just developed promises to reveal hidden facts concerning corrosion in metals, effect of contaminants in metals, soundness of electroplated coatings, etc. Also probes internal structure of foods, chemicals. **No. 1200**

Polyethylene Buchner funnel of 2-piece construction can now be obtained, claimed sturdy and easily cleaned. Takes 70 mm. filter paper. Perforated plate diameter 71 mm. **No. 1201**

Heptane and hexane in spectrophotometrically-pure grades are now available commercially. Each bottle is supplied with the absorbance curve for that particular lot, thus guaranteeing that impurities are negligible. **No. 1202**

New battery with practically unlimited shelf life is said to withstand temperatures from —70 to 170°F. Designed for low-current use, it weighs less than an ounce, is of completely dry construction, is rated at 95 volts. **No. 1203**

Spent fuel elements from AEC Materials Testing Reactor now available in limited quantity for rental to licensees as source of gamma radiation. Priority given to requests for elements for research and development activities. **No. 1204**

A micro-image data storage and retrieval device recently developed gives rapid access to any of 10,000 frames recorded in miniature on a 10 in. sq. sheet of microfilm. It automatically and continuously searches the film and photographs a frame every 2 seconds. **No. 1205**

Titanium in the form of a 50% cationic colloidal dispersion is now offered to the textile industry as a duller for synthetic fabrics and fibers. Said to give even exhaustion, good light reflectance and soft hand. **No. 1206**

Fluid turbidity can now be continuously monitored with a new dual beam unit, manufacturer claims. Instrument compares light scattered by suspended particles with light transmitted by the fluid. Usable on streams up to 3" diameter. **No. 1207**

N-Acetyl DL-Homocysteine Thiolactone is now commercially available for use in medical research, food technology, rubber stabilization, textile processing. Reacts with amino groups of amino acids, peptides or proteins to form new peptide bonds and a free sulfhydride group. **No. 1208**

Hot plate — magnetic stirrer combination is now offered to speed mixing and dissolving in the lab. Motor is effectively insulated from hot plate, it is claimed, and copper-jacketed heating elements eliminate magnetic interference and corrosion. **No. 1209**

About our authors

Harold A. Ohlgren, whose Fuel Cycle introduction leads off the series of articles on that subject, has recently (1953) returned to academic life after 17 years in industry. Now at the U. of Mich., his studies have to do with production processes for reactor-grade uranium, packaged high temperature nuclear heat power systems, recovery processes for spent fuels, and use of radiation in chemical and petroleum reactions.

Stephen Lawroski and **W. A. Rodger,** who analyze various routes to economic fission product separation, are director and associate director, respectively, of Argonne's Chemical Engineering Division. Lawroski has specialized on separations process technology, a subject he covered at the Geneva Conference in 1955. Rodger is a member of the Executive Committee of A.I.Ch.E.'s Nuclear Engineering Division.

Manson Benedict and **Tom H. Pigford** are well known to *CEP* readers. Benedict, a newly elected A.I.Ch.E. director, will be remembered for his article on research reactors (*CEP*, Feb. '55). Both men have been staff members in the chemical engineering department at M.I.T., where they have been organizing a program of study in nuclear engineering. Recently, Pigford announced his transfer to General Dynamics as chairman of the the Reactor Engineering Dept. of the firm's new Laboratory for Pure & Applied Science.

Bill Mecham, who with others authored the article on decontamination of spent fuel by distillation, has been pilot plant group leader in Argonne's chemical engineering division; **W. B. Seefeldt** has specialized in pilot plant design and operation, has recently concentrated on corrosion studies; **R. C. Liimatainen** and **R. W. Kessie** went to Argonne from Illinois Institute.

Also at Argonne are **Joseph H. Handwerk,** Ceramic group leader, and **Robert A. Noland,** Coating & Jacketing group leader, both in the Metallurgy Division.

J. E. Savolainen and **Raymond E. Blanco** are problem leader and section chief, respectively, in the Chemical Technology Division at ORNL. Blanco is in charge of the develop-

(*Continued on page* 44)


Lawroski


Benedict


Mecham

About our authors

(*Continued from page 43*)


Handwerk


Blanco


Raseman

ment of chemical methods for reprocessing reactor fuels. At ORNL since 1944, he started on electromagnetic separations. Savolainen got his atomic start in the army's Manhattan District.

Chad J. Raseman was introduced to atomic energy upon his arrival, in 1944, at Oak Ridge, dressed as a naval officer and reporting to an army colonel. Back in 1946 to the Naval Research Laboratory, he studied the feasibility of a nuclear submarine. He is currently at Brookhaven.

B. H. Thompson, with **Bob Clouse** and **Joe Dykstra,** supervised the design and operation of the uranium recovery system at the Oak Ridge gaseous diffusion plant, are also associated with fluorine and UF_6 production.

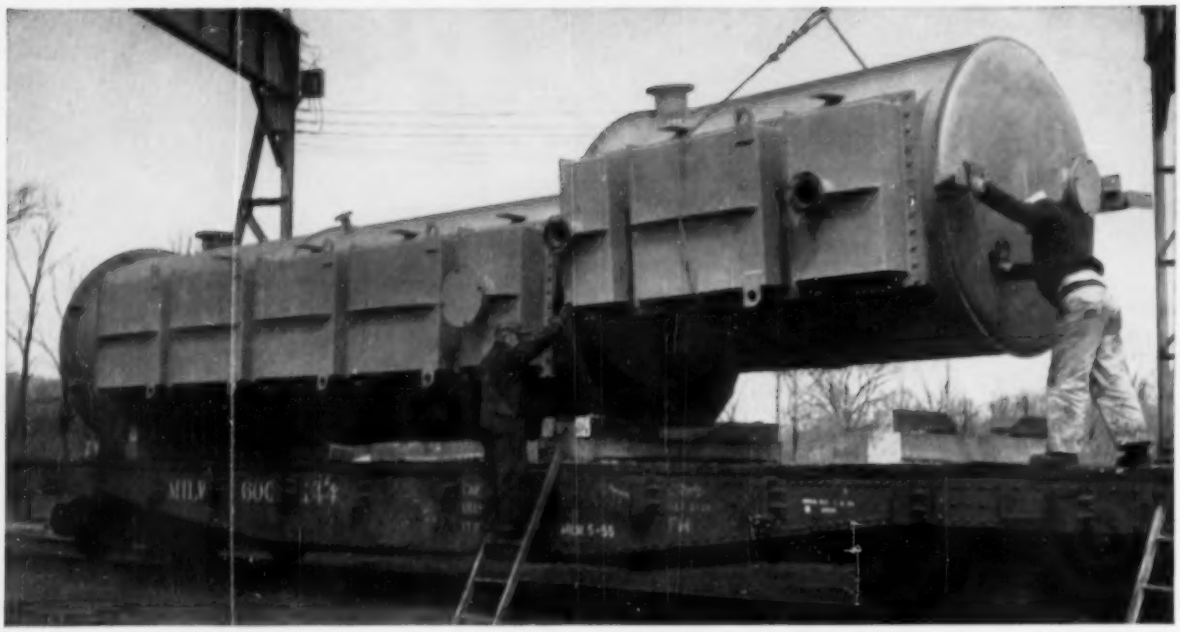
A. M. Aikin, who writes on ion exchange, has been at Chalk River Project of Atomic Energy of Canada, Ltd., for the past seven years, was made head of the Chemical Engineering Branch last July.

M. J. Stedwell and **R. E. Burns** are at Hanford, the locale of their article on waste disposal. Burns and co-workers completed the laboratory development studies of the precipitation process described. Stedwell and others engineered and provided assistance during process testing and stabilization.

J. W. Blanton, who is the author of the "how to get business" article, is a chemical engineer who attended Harvard Graduate School of Business Administration. After duties with A. D. Little, Inc., he joined the Commercial Development Dept. of National Research Corp., is now manager of sales development for NRC Metals.

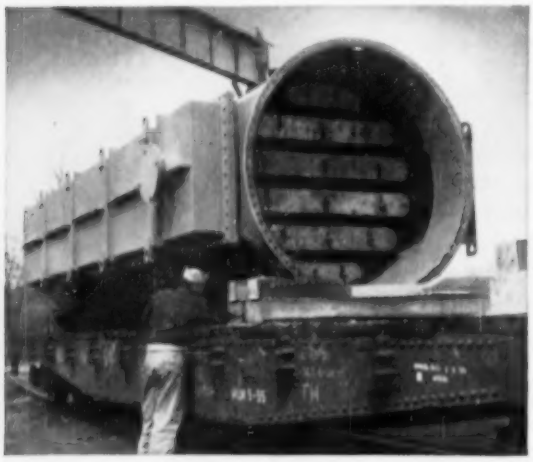
D. S. Arnold and **B. G. Ryle,** with associates, were responsible for trouble shooting during startup of the uranium digestion and extraction facilities at National Lead's Fernald operation; have also been responsible for process development in digestion and extraction projects.

Also at Fernald, **E. R. Johnson, E. O. Rutenkroger, A. B. Kreuzmann,** and **B. G. Doumas** have acted as a team responsible for developing processing methods for recovering uranium from scrap materials.



First fabricated ammonia still...built at Downingtown for Koppers Company, Inc.

When Koppers Company, Inc., Engineering and Construction Division designed this welded carbon steel plate ammonia still to replace its previous cast iron design, it naturally chose the fabricator with care. Close tolerances were required on positioning of risers, riser slots, bells, trays and weirs. We're proud of the part Downingtown had in this pioneering effort. This still is used for stripping the ammonia from ammonia liquor produced in a chemical recovery coke plant.



THE UNIT WAS BUILT TO THE FOLLOWING SPECIFICATIONS:

Inside Diameter: 7'0"
Over-All Height: 37'10"
Design Data: 12 psi, 650° F.
Operating Data: 7 psi, 250° F.
Shop Test: 12 psi hydrostatic for 90 min.
Total Weight: 60,000 pounds

Send for bulletins describing our experience and facilities.

◀ Interior of bottom section, showing position of rectangular bells fabricated from stainless steel, type 410. Thirteen trays, with bells.

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HEAT EXCHANGERS—STEEL AND ALLOY PLATE FABRICATION
CONTAINERS AND PRESSURE VESSELS FOR GASES, LIQUIDS AND SOLIDS

Last year started with a more or less general optimism, especially in the chemical industry, with high hopes for a record year. This year is beginning with a good many uncertainties in the outlook both in the domestic business picture and in the foreign field. However, chemical leaders are far from pessimistic about the year's outlook in their own industry.

Earnings of the big chemical firms in 1956 were in a good many cases disappointing because they fell short of the record figures in 1955. Although sales continued to gain, the higher cost of wages, of freight, and of raw materials held profits down. The steel strike was also a factor.

All of this, added to at intervals by disturbing news from abroad, brought a declining stock market at the beginning of 1957. Lower stock prices in themselves are an unsettling factor, not only to investors, but to business men, who fear they may be a barometer forecasting future business trends.

Chemical shares are mostly in the "blue chip" class and sell at very high prices in relation to earnings on the theory that the chemical industry is a growth industry and that each year's profits should be better than the last. When it was revealed that earnings last year were actually running behind the preceding year in a number of instances, a good many investors sold their stocks. But there now seems to be a belief in high chemical circles that this pessimism has been overdone. Present expectations are for a better year in 1957.

One large company, for example, did a new high record business in January and at present is budgeting a record sales volume for 1957.

Some Uncertainties . . .

There were a few disturbing signs in January in other segments of industry that adversely affected stock prices. General Motors, for example, announced that it would delay construction of a huge new assembly plant for Buick, Oldsmobile, and Pontiac to be built near San Francisco, supposed to cost $50 million. General Electric Co. also has postponed work on four new plants. All of this, plus lagging sales of automobiles, has brought repercussions in the steel industry and cancellations of orders placed for March delivery. Some steel mills have reported that March tonnage has been cut in half by some customers in the automotive field. Of course there is still hope that a pickup will come before spring.

The feeling currently is that buying of steel by the motor industry is not expected to pick up immediately. The automobile people stocked up substantially before last year's steel strike and now apparently plan to keep their buying closely in line with consumption.

The motor industry, of course, is a major chemical consumer, taking huge amounts of lacquers and paints, increasing amounts of plastics per car, and synthetic fibers for upholstery and other materials. So economists both in financial and in chemical circles are watching events in Detroit closely.

As the new year moves on, the foreign situation still holds many explosive possibilities in spite of the stopping of hostilities between Egypt and Israel. But Russia can be depended upon to create new diversions in the Middle East whenever possible, which will keep that area in a ferment. Clearing of the Suez Canal will help European oil supplies, but there may well be other threats to oil sources that will further upset Great Britain.

The Eisenhower policy of aid to the Middle East (if asked for) may eventually also take the form of money and technical help to underdeveloped nations, thus providing new jobs for chemical engineers.

. . . But Not for Chemicals

Meanwhile, in the midst of all these uncertainties, the chemical industry is planning to go ahead with the biggest expansion program in its history. According to a just-released Manufacturing Chemists' Association survey, the chemical industry will spend an estimated $2.5 billion on new domestic chemical construction through 1957 and 1958. (In 1956 new facilities brought into production cost more than $1.1 billion.)

Allied Chemical & Dye announced that it will spend in 1957 somewhat more than the $76 million capital expenditures in 1956. Union Carbide & Carbon, which spent about $130 million in 1956, is understood to be planning a very much larger expansion program this year. Dow Chemical is similarly planning a record expansion budget, though definite figures are not available. All of this will take steel and help out steel firms by taking up part of the slack which might come from an automotive slowdown. Big chemical firms are obviously not in the least worried about the tight money situation, expected to continue during this year. Funds from plant expansion will come from "cash inflow" derived from depreciation, amortization, and surplus earnings.

The chemical industry is taking an increasingly keen interest both in research in the nuclear field and in commercially practical projects in that area. Allied Chemical, for example, has made its first venture into the field with a new process and a new plant to make uranium hexafluoride (using its own hydrofluoric acid) for the gaseous diffusion plants of the Atomic Energy Commission. Other firms are trying to get into other manufacturing activities to serve the new field.

CEP

opinion and comment

CHEMICAL ENGINEERING AND THE NUCLEAR FUEL CYCLE

The fields of interest and activity in chemical engineering are many and diverse. One of the most recent of these to attain recognition is the nuclear Fuel Cycle. This is a field so diverse within its own structure that it ranges from ore processing to fission product separation from re-useable fuel. Like many other fields dependent upon the peculiar skills of the chemical engineer, this one is also participated in by other groups likewise making important contributions.

As is often the case, recognition by members of a profession and others in industry, government, the public, etc. doesn't "just happen." Certainly, in the case of the Fuel Cycle, it has taken the efforts of dedicated, visionary, yet thoroughly practical leaders in chemical engineering to bring about this accomplishment. What happened was: *first*, establishment of an understanding of the advantages and goals to be attained; *second*, creation of a climate of understanding on the part of other major participating groups that the chemical engineers' contribution to the Fuel Cycle field was sufficient to justify their taking leadership in mobilizing and getting presented the information all related groups will need.

A year ago, a decision was reached by leaders of the Nuclear Engineering Division (N.E.D.) of A.I.Ch.E. that N.E.D. would go ahead with this role of stimulating and drawing out useable information about the Fuel Cycle. The several sessions sponsored by N.E.D. in the 2nd EJC Nuclear Congress are but the first of others that will be forthcoming.

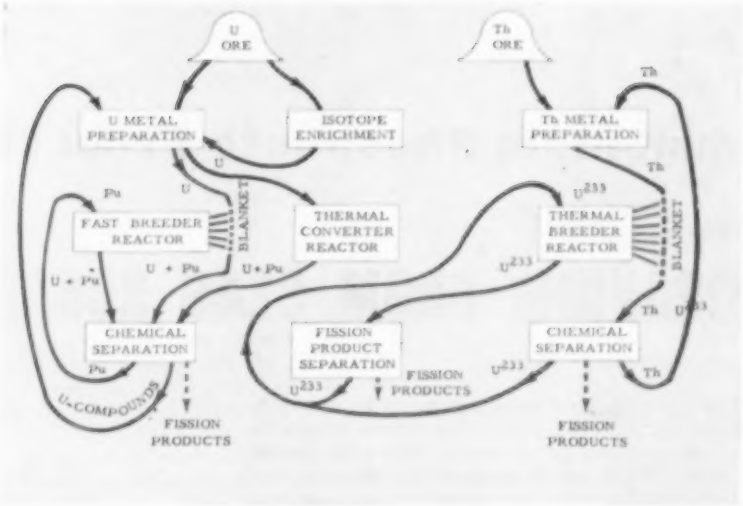
"The decision that N.E.D. should take the leadership in evolving the information pattern of the Fuel Cycle," explains N.E.D. chairman Herbert Isbin, "crystallizes the role of N.E.D. as being primarily of service to chemical engineers interested in the nuclear energy field.

"It also means," continued Isbin, "that while N.E.D. expects to serve most directly their interests, it will act with keen awarenesss of the benefits to be derived from its actions by other specialist groups. The Division will therefore work closely with these groups in joint activities."

The importance of N.E.D. is doubtless re-emphasized by this decision and the action that has ensued, not only by Division members, but also by all others interested in the evolution of chemical engineering. Another activity already under way by N.E.D. and deserving of mention is a conference being sponsored at the next Annual Meeting (Chicago, December 1957) on the economics and technology of the use of nuclear reactors as direct producers of high temperatures for chemical processing. These reactors can also provide synthesis-activating radiation. Closer to practical realization than most realize, such reactors form a most fit subject for discussion by chemical engineers. This, as well as the current activity of N.E.D., represents noteworthy effort which will doubtless be well received.

—JBM

Outstanding assistance in the preparation of this special nuclear issue of **CEP** was received from the following individuals: Herbert Isbin (University of Minnesota) chairman, N.E.D. (who served as A.I.Ch.E.-N.E.D. program representative to the EJC program committee) and W. Kenneth Davis (director, Division of Reactor Development, AEC) vice-chairman and program chairman, N.E.D., for their general guidance; Harold A. Ohlgren (University of Michigan) for counsel in the selection of material for publication; George Jenkins and associates (Union Carbide Nuclear Company), for preliminary evaluation of the novelty and chemical engineering significance of manuscript contents; F. L. Cuthberth, Floyd Culler, E. B. Gunyou, J. C. Robinson, F. G. Foote, R. B. Briggs, R. B. Richards, S. Lawroski, S. M. Stoller, M. Levenson, and J. Hogerton, as co-chairmen and organizers of Fuel Cycle sessions. E. J. Brunenkant, director of Industrial Information for AEC, provided both factual information as well as contact with specialist sources within the AEC.



In the above Fuel Cycle diagram, the stream leaving the Thermal Breeder Reactor Blanket (right) should be indicated as containing $Th+U^{233}$. The stream loop (extreme right) from Chemical Separation to Th Metal Preparation should include Th only.

THE FUEL CYCLE

Our nuclear future is already with us. The AEC's request for power reactors ready for operation by 1962 calls for immediate engineering planning, not only of the reactors themselves, but also of the related facilities. Utmost in importance to the achievement of economically competitive nuclear power is The Fuel Cycle, represented by all but one (i.e., reactors) of this breakdown of the fields of nuclear energy:

- Milling and concentration of uranium and thorium ores.
- Production of reactor-grade uranium and thorium.
- Isotope separations of U^{235} from U^{238}.
- Fabrication and assembly of reactor fuels and fertile materials.
- Production of fuel element structural materials (such as zirconium, special aluminum, and stainless steels).
- Heat power reactors with associated power plants.
- Reprocessing of reactor fuels for recovery of U^{235}, U^{233}, U^{238}, and Pu^{239}.
- Processing of radiochemical wastes and waste disposal.

In each of these fields there are encountered problems of heat transfer, fluid flow, mass transfer, momentum transfer, crystallization, leaching, diffusion, distillation, extraction, absorption, adsorption, materials handling, mixing, and drying. From this it can readily be seen why chemical engineers have unique qualifications for making major contributions to the nuclear energy field. Putting these skills to such work means correlating nuclear parameters with those associated problems often found in chemical engineering activity—an accomplishment which in its more detailed aspects may call for extension of one's training in mathematics, plus some nuclear physics.

Achievement of desired results—ultimate competitive economics in generating useful work and power from the fission mechanism—will be dependent upon the following conditions:

- The engineering feasibility of design, construction, and operation will have to be carefully evaluated in terms of a number of different types of process steps integrated into composite plant designs.
- From process engineering studies, it will be necessary to examine the economics and technical aspects of building industrial nuclear facilities as a function of time.
- The engineer will need to determine the additional research and development programs needed to meet the economics of competition.
- Process engineers will be required to recommend to their respective managements the specific roles which their firms should undertake in designing, building, and operating such nuclear facilities.

On this page is a simplified diagram of The Fuel Cycle, the purpose of which is to illustrate the interrelationships of the fields of nuclear energy listed above, and to suggest, at least, the complexity of the problem confronting the engineer and technologist. It should also be appreciated that the *reliability* of economics in any specific area of the diagram is contingent upon complete understanding of the impact and influences of areas closely related and associated.

Further, the articles presented in this issue of *CEP* point up dramatically the technical data, evaluations, systems analyses, and economic aspects of a number of alternative routes to specific goals. The achievement of tomorrow's nuclear power will require not only careful examination and delineation of these routes, but also the development of others by the chemical engineer.

—H. A. Ohlgren

Harold A. Ohlgren is Professor of Chemical Engineering at the University of Michigan.

The Uranyl — Ammonium Phosphate Process for RECOVERY OF URANIUM FROM SLAG SCRAP

Thousands of tons of slag scrap await processing to remove its valuable uranium content. AEC has invited private industry to undertake the task, is asking for proposals. Here is the process already in use at Fernald, which produces a high-grade concentrate suitable as feed material for uranium refining operations.

E. R. Johnson, E. O. Rutenkroger, A. B. Kreuzmann, and B. C. Doumas

National Lead Company of Ohio, Cincinnati, Ohio

At the A.E.C.'s Feed Material Production Center (F.M.P.C.) at Fernald, Ohio,* uranium metal is produced by the reaction of a mixture of uranium tetrafluoride and magnesium metal in a refractory-lined bomb (*1, 2*). This thermit-type reaction takes place in accordance with the following equation:

$$UF_4 + 2Mg \rightarrow U + 2MgF_2 \qquad (1)$$

The contents of the bomb are heated to the reaction temperature and the reaction proceeds exothermically. The products of the reduction, that is, uranium metal and magnesium fluoride, separate while they are still molten, the uranium settling to the bottom of the bomb. On cooling, the MgF_2 solidifies and traps droplets of uranium which have not settled from the mixture.

The slag, as it is removed from the bomb, is, of course, predominantly magnesium fluoride containing uranium metal in various degrees of agglomeration and a small amount of magnesium metal. There are also trace quantities of uranium oxide and magnesium oxide present in the slag. Thousands of tons of this scrap material have accumulated, and inasmuch as significant quantities of uranium are contained in it, the A.E.C. has asked that private industry undertake the operation of refining the slag for uranium recovery.

Of importance to this recovery program is a process which has been developed for recovering uranium from such slag in the form of a high-grade uranium concentrate of such grade as to be suitable for use as a feed material for the F.M.P.C. Refinery. In this way, the scrap uranium can be returned to production channels.

The process developed involves the following steps:

(1) roasting and grinding of the scrap material
(2) leaching the roasted and ground material with hydrochloric acid to solubilize the uranium
(3) precipitating the uranium from the filtered leach liquors as $UO_2NH_4PO_4$
(4) converting the $UO_2NH_4PO_4$ to $Na_2U_2O_7$ by slurrying of the former with a sodium hydroxide solution.

This article describes the details of this recovery process and the equipment which is used in plant-scale processing.

Process Description

A schematic flowsheet of the recovery of uranium from MgF_2 slag by the phosphate precipitation process is shown in Figure 1. The following sections describe the details of the individual operations.

FEED PREPARATION

The MgF_2 slag is crushed to −4 mesh and roasted for 1 hr. at about 800° C. This treatment, serving to oxidize the metallic uranium and magnesium present in the scrap, thereby facilitates grinding and prevents the formation of hydrogen during leaching. Reactions which take place to varying extents during roasting are depicted by the following equations (*3, 4*).

$$4U + 5O_2 \rightarrow UO_2 + U_3O_8 \qquad (2)$$

$$3U + 4O_2 \rightarrow U_3O_8 \qquad (3)$$

$$2Mg + O_2 \rightarrow 2MgO \qquad (4)$$

$$2U + 3O_2 + MgO \rightarrow MgU_2O_7 \qquad (5)$$

$$UO_2 + U_3O_8 + O_2 + 2MgO \rightarrow 2MgU_2O_7 \qquad (6)$$

$$2U_3O_8 + 3MgO + O_2 \rightarrow 3MgU_2O_7 \qquad (7)$$

$$2U_3O_8 + 3MgF_2 + O_2 + 3H_2O \rightarrow 6HF\uparrow + 3MgU_2O_7 \qquad (8)$$

$$MgF_2 + H_2O \rightarrow MgO + 2HF\uparrow \qquad (9)$$

When roasting has been completed, the MgF_2 slag is pulverized to 90% −325 mesh.

HYDROCHLORIC ACID LEACH

The roasted and ground MgF_2 slag is leached with hydrochloric acid for 3 hr. at 85 to 90° C., in the presence of an oxidant ($NaClO_3$), to solubilize the uranium. The leaching operation is conducted at a pulp density of about 15% solids. The leach liquor is maintained at *p*H 0.5, or less, throughout digestion. Upon completion of the digestion period, the slurry is filtered and the residue is washed with a volume of water equal to about 20% of the total slurry volume. The residue must contain less than 0.05% uranium (dry basis) before it can be discarded to the tailings pile.

* Operated by the National Lead Company of Ohio.

Effects of the particle size of the slag and of the digestion temperature on the rate of uranium solubilization during leaching are shown in Figure 2.

PRECIPITATION

The filtrate resulting from the filtration of the MgF_2 slag digest liquors is treated with 75% phosphoric acid, with the use of a PO_4:U wt. ratio of 0.6:1, and then is adjusted to pH 1.5 with ammonium hydroxide to precipitate the uranium, presumably as $UO_2NH_4PO_4$ (U.A.P.). The slurry resulting from precipitation of the uranium is filtered and the U.A.P. cake is washed with a volume of water equal to about 20% of the total slurry volume.

Effects of pH and phosphate concentration on the efficiency of uranium precipitation are shown by the results of the laboratory experiments outlined in Table 1. It was found that a PO_4:U wt. ratio of 0.4:1 and 0.5:1 effected the precipitation of 90 and 99+% of the total uranium content of the leach liquors, respectively. Since the theoretical PO_4:U wt. ratio in uranyl ammonium phosphate is 0.4:1, the preceding results indicated that the precipitation of uranium from the leach liquors was essentially quantitative when the theoretical phosphate requirement was employed. The use of large excesses of phosphate was effective in precipitating additional uranium from the trace concentrations remaining in solution, but it is doubtful whether such recovery would be economical during plant processing.

It was observed also that uranium precipitation was essentially complete at pH 1.0 when a PO_4:U wt. ratio of 0.5:1 was used. The use of a higher pH (up to 2.0) was effective in precipitating a large percentage of the trace quantities of uranium remaining in solution. The possibility of coprecipitation of fluorides at the higher pH values suggested the advisability of conducting the precipitation at pH 1.2 to 1.7.

CAUSTIC TREATMENT

The U.A.P. cake is slurried with a 5% sodium hydroxide solution with a 1:1 wt. ratio of NaOH:U. This treatment serves to convert the uranium into the form of a sodium-diuranate-type product, solubilizes most of the phosphate, and volatilizes ammonia.

$$2UO_2NH_4PO_4 + 8NaOH \rightarrow Na_2U_2O_7\downarrow + 2NH_3\uparrow + 2Na_3PO_4 + 5H_2O \qquad (10)$$

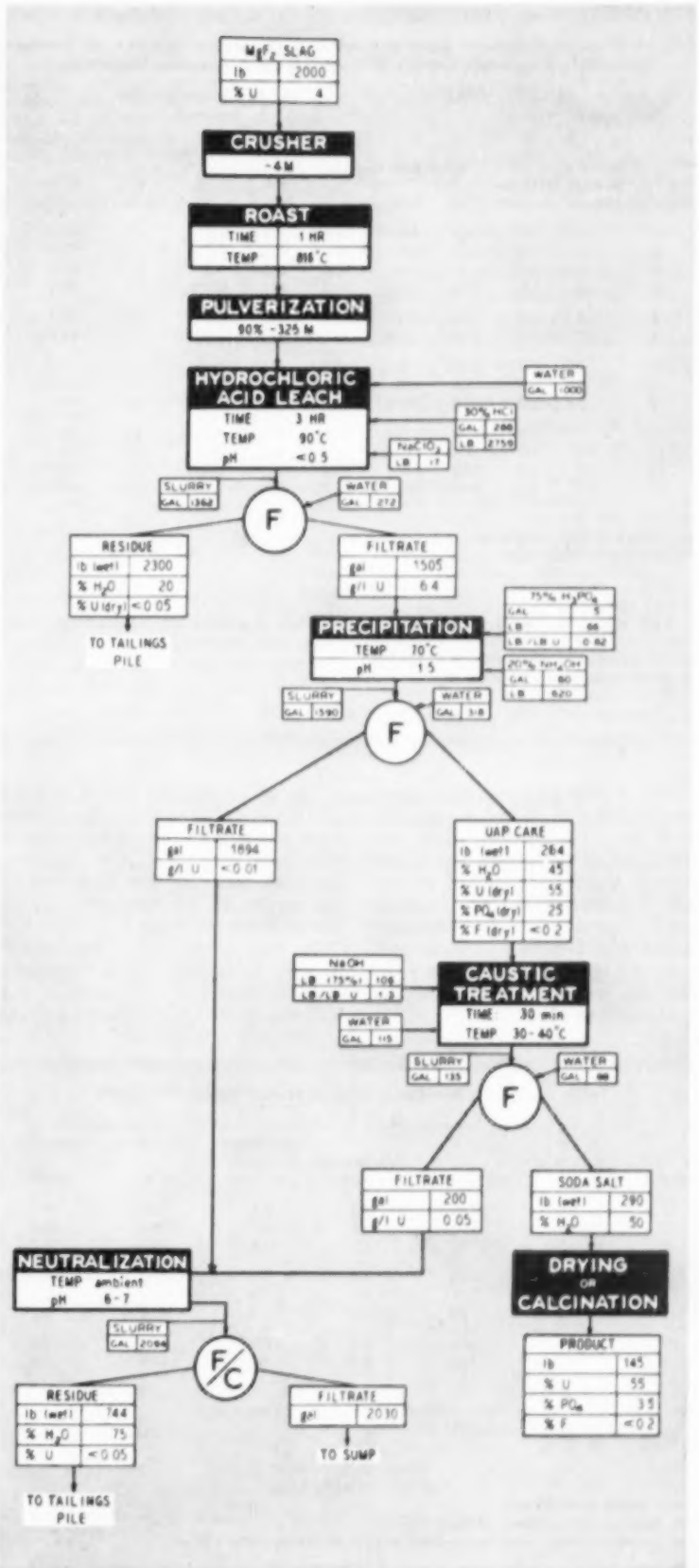


Fig. 1. Process flowsheet—recovery of uranium from MgF_2 slag by uranyl ammonium phosphate process.

Table 1.—Effect of Phosphate Concentration and pH on Precipitation of Uranium from MgF_2 Slag Leach Liquors (HCl) as Uranyl Ammonium Phosphate

			U.A.P. cake analysis			Filtrate from precipitation treatment analysis			
Trial No.	PO_4/U wt. ratio in leach liquor	Precipitation pH	U(%)	F(%)	PO_4(%)	vol (ml.)	U (g./liter)	PO_4 (g./liter)	% total U precipitated
1	.4	1.0	60.5	0.05	24.4	630	1.6	0.01	90.4
2	.4	1.5	60.6	0.06	24.2	620	1.7	0.01	90.0
3	.4	2.0	60.1	0.06	24.3	640	1.5	0.01	90.9
4	.5	1.0	60.2	0.05	24.3	620	0.036	0.8	99.8
5	.5	1.5	58.2	0.19	25.2	630	0.006	0.4	99.9+
6	.5	2.1	53.6	0.64	24.1	620	0.002	0.4	99.9+
7	.75	1.0	60.0	0.06	24.7	635	0.035	4.4	99.8
8	.75	1.5	58.3	0.08	26.1	625	0.002	3.5	99.9+
9	.75	2.0	58.2	0.15	26.0	630	0.001	3.8	99.9+
10	.75	2.5	57.3	0.44	26.3	640	0.0008	2.8	99.9+
11	1.5	1.0	59.4	0.05	25.7	630	0.028	15.8	99.8
12	1.5	1.5	59.6	0.07	26.2	660	0.003	14.5	99.9+
13	1.5	2.0	57.7	0.06	26.9	640	0.0009	15.2	99.9+

Notes

a. Volume of MgF_2 slag leach liquor treated in each trial: 500 ml. (pH 0.2)

b. Analysis of leach liquor:

U(g./liter)—21
F(g./liter)— 4

c. 85% H_3PO_4 was added to the filtered leach liquors to produce the indicated PO_4/U wt. ratios

d. pH adjustments made with 28% NH_4OH

e. Precipitation time: 5 min.

f. Precipitation temperature: 40° C.

g. Volume of water used for washing U.A.P. cake: 100 ml.

Such a treatment is desirable in the production of a feed material for the F.M.P.C. Refinery as large concentrations of phosphates in the feed material complicate refinery processing. The slurry resulting from the caustic-treatment step is filtered and washed with a volume of water equal to about 65% of the total slurry volume. The sodium diuranate product is dried at 550 to 650° C.

The effects of pulp density and the NaOH:U wt. ratio used in the caustic-treatment step on the solubilization of phosphate from the U.A.P. cake during such treatment are illustrated by the results of the laboratory experiments shown in Table 2.

It was found that treatment of U.A.P. containing 25.7% phosphate with a NaOH:U wt. ratio of 1:1 (30 min. at 35° C.) produced a sodium-diuranate-type product containing 5 to 7% phosphate.

Treatment of samples with a NaOH:U wt. ratio of 1:1 at various slurry densities (30 min. at 35° C.) indicated that the pulp density of the slurry had little effect on phosphate solubilization.

Table 2.—Caustic Treatment of Uranyl Ammonium Phosphate

					Analysis of sodium diuranate	
Trial No.	wt. NaOH (g.)	vol. H_2O(ml.)	Pulp density (% solids)	Approximate NaOH/U wt. ratio	U(%)	PO_4(%)
1	3.8	325	3.5	0.5	51.8	20.3
2	3.8	100	8.4	0.5	53.5	20.8
3	3.8	25	16.1	0.5	58.2	18.2
4	7.5	325	3.5	1.0	61.8	6.8
5	7.5	100	8.4	1.0	62.6	5.5
6	7.5	25	16.1	1.0	66.0	5.2
7	15	325	3.5	2.0	65.3	3.5
8	15	100	8.4	2.0	66.7	3.4

Notes

a. 58 g. of wet uranyl ammonium phosphate used in each trial.

b. Analysis of uranyl ammonium phosphate

H_2O(%)—77
U(%)—54.8 (dry basis)
PO_4(%)—25.7 (dry basis)

c. Reaction time: 30 min.

d. Reaction temperature: ambient

e. Volume of water used for washing sodium diuranate cake: 100 ml.

NEUTRALIZATION

Because of tailings disposal problems, the acid liquors from the precipitation step and the alkaline liquors from the caustic-treatment step are combined and adjusted to neutrality. The resulting slurry is then either filtered or centrifuged, the liquors discarded, and the solids sent to the tailings pile.

URANIUM RECOVERY EFFICIENCY

The over-all uranium recovery efficiency for the phosphate precipitation process is in excess of 98%. This includes the losses incurred in the leached tailings and the filtrates from precipitation and caustic-treatment operations.

Description of Plant Processing Equipment

A schematic equipment flowsheet for the phosphate precipitation process is shown in Figure 3.

The scrap material is conveyed to a large storage silo by means of a bucket elevator. This silo discharges into a vibrating conveyor which transports the scrap material to a magnetic separator. After the tramp iron has been removed from the material, the latter is crushed in a gyracone crusher and discharged into another bucket elevator which conveys the crushed material to the top hearth of a Herreschoff furnace. The scrap passes through the furnace and is discharged into a cooling screw conveyor which transports it to a third bucket elevator. This elevator discharges into a surge bin which feeds a ring-roll crusher. The pulverized material is blown through an air classifier and collected in a cyclone separator which discharges to a prepared feed bin. The roasted and ground material then is weighed in a weigh hopper and conveyed to the digestion tanks where the uranium is extracted by leaching with hydrochloric acid.

Upon completion of digestion, the digest slurry is pumped to a filter feed tank and then to a set of hydraulic cones arranged in parallel. The underflow from the hydraulic cones is filtered on a pan filter while the overflow from the cones and the filtrate from the pan filter is filtered on a precoated rotary vacuum filter. The filtration rate of the slurry on this filter is about 15 gal./(hr.)(sq.ft. of filtration surface). The solids collected from both the pan filter and the rotary vacuum filter are discharged to a trailer which periodically transports the uranium-barren material to the tailings dump.

The filtrate from filtration of the MgF_2 slag digest liquors is pumped to the precipitator where phosphoric acid is added and the filtrate adjusted to pH 1.5 with the use of ammonium hydroxide.

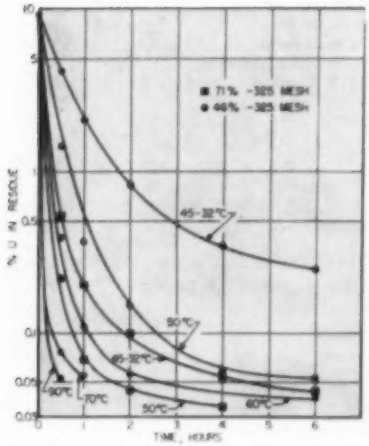


Fig. 2. Effect of temperature and particle size on leaching rates of MgF_2 in HCl.

Both reagents are added continuously. The precipitated slurry overflows from the precipitator into a filter feed hold tank which supplies the slurry to a precoated rotary vacuum filter. The filtration rate of this slurry averages about 15 gal./(hr.)(sq.ft. of filtration surface). The filtrate from this operation is pumped to the neutralization tank while the U.A.P. cake is conveyed to the caustic-treatment tank by means of a screw conveyor. Upon completion of caustic treatment the resulting slurry is filtered on a precoated rotary vacuum filter. The filtration rate of the caustic slurry is about 9 gal./(hr.)(sq. ft. of filtration surface). The sodium diuranate cake is conveyed to a Moyno pump which feeds the material to a multiple-hearth dryer. The filtrate from this operation is pumped through a polishing filter to the neutralization tank where it is used to neutralize the filtrate from the precipitation operation. The resulting slurry is then either filtered or centrifuged, the filtrate is pumped to the general sump and the cake is conveyed to a tailings trailer by a screw conveyor.

Off-gases from the furnace and dryer, and fumes from the digestion tanks are vented to the atmosphere through venturi-type gas scrubbers. Spent scrubber liquors, process spills, and pump seal water are used as make-up water in digestion batches. All operations which involve the handling of dry solids are vented to dust collectors.

Conclusions

The phosphate precipitation process has been successful in recovering uranium from MgF_2 slag in yields in excess of 98%. The resulting sodium-diuranate-type product generally assays 55% uranium, 3 to 5% phosphate and <0.2% fluoride.

Uranium concentrates which are used as feed materials for the F.M.P.C. Refinery must not contain any significant quantities of fluorides because the latter presents a corrosion hazard to refinery equipment (*5*). The uranium concentrates, obtained by recovery techniques in which uranium is precipitated from MgF_2 slag leach liquors (HCl) by the use of MgO, CaO, or NH_4OH at *p*H 5 to 6, are contaminated with significant quantities of fluoride (10 to 15%) (*6*). In the phosphate process, however, there is little or no coprecipitation of fluoride with uranium as the precipitation is conducted at a *p*H below that at which the fluoride separates.

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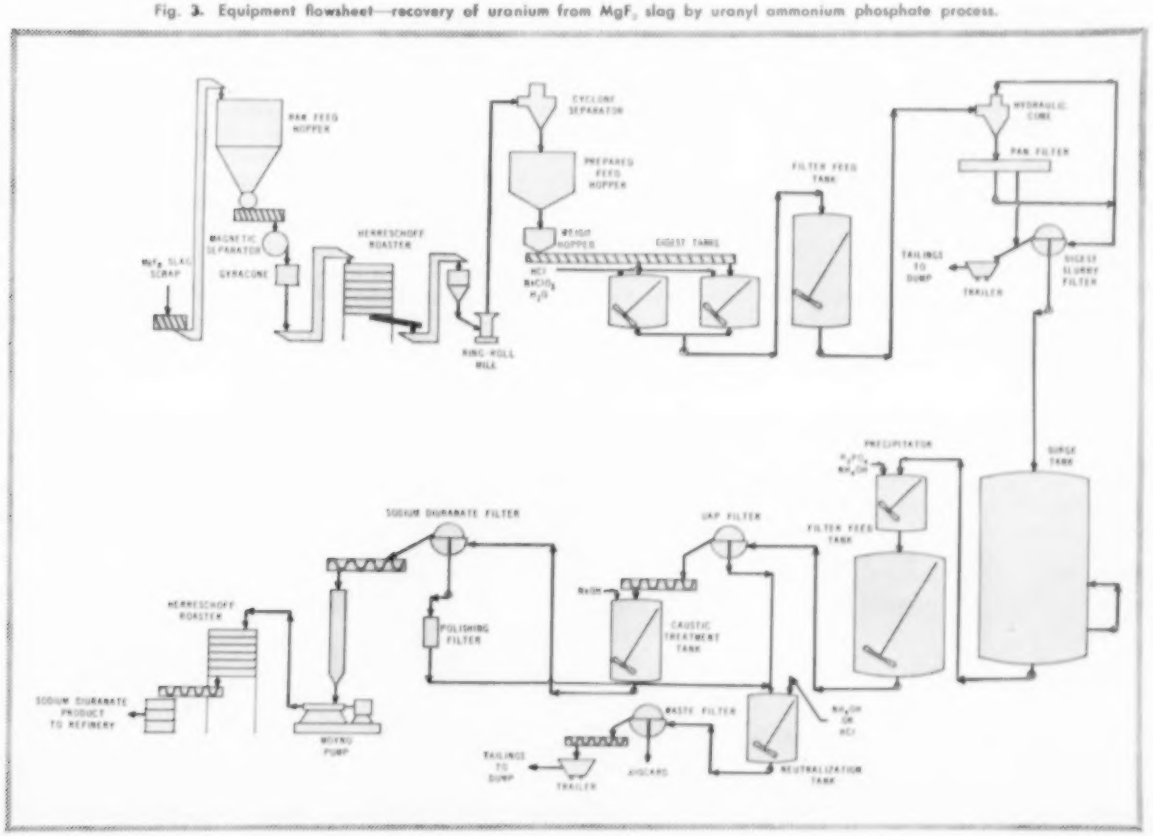
To be presented at 1957 Nuclear Engineering and Science Congress, Philadelphia, Pennsylvania.

Fig. 3. Equipment flowsheet—recovery of uranium from MgF_2 slag by uranyl ammonium phosphate process.



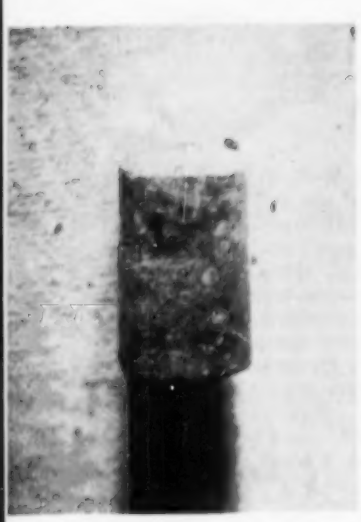


Fig. 1. ThO_2-2.5 wt. % UO_2. Burn-up: 0.05 a/o total metal. Zircaloy cladding has been removed. Exposure in 500-515° F. water.

Nuclear reactors operating in the higher temperature regions are expected to use ceramic fuel elements. Among the problems inherent in such fuels, particularly the ceramics, are high internal temperatures due to poor thermal conductivity and escape of volatile fission products due to fissuring. Described are thoria-urania fuel elements which have, among their several advantages, corrosion resistance to water at high temperatures.

OXIDE FUEL ELEMENTS
for high temperatures

J. H. Handwerk and R. A. Noland | Argonne National Laboratory, Lemont, Illinois *

Urania (UO_2) and thoria (ThO_2) have long been used as refractory materials for melting metals such as uranium. Ware made of UO_2 must be sintered in a vacuum or protective atmosphere to prevent oxidization of the UO_2 to U_3O_8, while ware made of ThO_2 may be sintered in air since ThO_2 will not form a higher oxide. Both UO_2 and ThO_2 have face-centered cubic- or fluoride-type structures and, as shown by Lambertson (*1*) and others, they will form a complete series of solid solutions. This stability of ThO_2 as well as its conversion to U^{233} would indicate the possibility of a power reactor fuel composed primarily of ThO_2 with a small amount of enriched UO_2 to cause criticality. Through the Th-U^{233} cycle, thorium can be converted to fissionable material.

Both thorium and uranium metal are susceptible to corrosion by water and these metals must be carefully clad with a corrosion resistant material when used in water-cooled reactors. The oxides or the common corrosion product of thorium and uranium are corrosion resistant to water, and these materials are more suitable for nuclear fuels.

Preliminary Considerations

The work of Warde (*2*) and of Hoekstra (*3*) indicated that U_3O_8 is stable in an oxidizing atmosphere up to about 1,150° C. With prolonged heating above this temperature range, U_3O_8 decomposes to a lower oxide and, eventually, to UO_2. In order to eliminate the use of a protective atmosphere in sintering UO_2, and in order to avoid the disruptive volume change, during sintering, of UO_2 to U_3O_8 (below the decomposition temperature of U_3O_8), UO_2-ThO_2 solid solution compositions were prepared with UO_2 added as an equivalent amount of U_3O_8.

Mixtures of U_3O_8 and ThO_2, containing up to 30 wt. % U_3O_8, were dry pressed into small right cylinders ¼ in. in diameter. These compositions were fired to 1,700-1,750° C. in air. The resultant ware appeared to be free of cracks or other visible defects, and underwent no visible changes when reheated in air to 1,400° C. for periods as long as 96 hr. The geometric densities of these samples ranged from 7.85 g./cc. for compositions containing 2½ wt. % UO_2 (added as an equivalent amount of U_3O_8) 97½ wt. % ThO_2 to 7.00 g./cc. for compositions containing 30 wt. % UO_2 (added as an equivalent amount of U_3O_8), and 70 wt. % ThO_2.

X-ray diffraction analyses of samples showed diffraction patterns of the fluoride type which are characteristic of thoria-urania solid solutions. No extraneous lines were observed even though a careful search was made for any U_3O_8 lines.

Specimens of two compositions were irradiated in both the M.T.R. (materials testing reactor) and the CP-5 reactors. The initial irradiation tests

Fig. 2a. ThO_2-2.5% UO_2. Burn-up: 0.88% total metal. Irradiated bare, packed in steel wool.

Fig. 2b. Typical jacketed specimen with 0.020-in. hole.

* Mr. Handwerk is Associate Ceramic Engineer and Mr. Noland Associate Metallurgy Engineer.

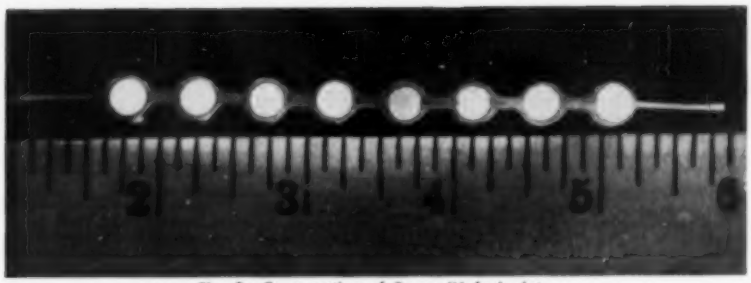


Fig. 8. Cross section of Borax IV fuel plate.

were made on a body having a composition of 97½ wt. % ThO_2 – 2½ wt. % UO_2 (added as an equivalent amount of enriched U_3O_8). The average apparent density of these specimens was found to be 9.27 g./cc. and the average apparent porosity was found to be 8.13%. As these were initial test specimens, the geometric density of the specimens was not determined. These pellets were encased in Zircaloy-II and stainless steel cans with the annulus filled with gas or NaK. Burn-out in the CP-5 tests ranged from 0.02 a/o to 0.05 a/o (Total Metal Atoms). These tests were made in water autoclaves at temperatures of 500 to 520° F. at pressures of 680 to 810 lb./sq.in. Surface heat flux was estimated to be 6×10^4 B.t.u./(hr.)(sq.ft.). Burn-out in the M.T.R. reactor ranged 0.2 a/o to 0.95 a/o (Total Metal Atoms). These samples were subjected to approximately 50 scram cycles, and a few of the specimens were irradiated bare or in cans in which a 0.020-in. hole had been drilled. Postirradiation examination revealed that the CP-5 specimens were intact; however, a few had fragmented. A typical view of these specimens is shown in Figure 1. The specimens from M.T.R. appeared to be sound; however, microscopic examination revealed that a few cracks had developed in the samples. Two specimens irradiated bare, but packed in steel wool to prevent mechanical damage, were found to be completely free of visible damage. One of these specimens is shown in Figure 2. This specimen was irradiated to a burn-out of 0.88 a/o of the total metal atoms. Other specimens irradiated in either Zircaloy-II or stainless steel cans appeared to be sound; however, microscopic examination revealed that a few cracks had developed.

Irradiation tests were also made on a body having a composition of 90 wt. % ThO_2 – 10 wt. % UO_2 (added as an equivalent amount of enriched U_3O_8). Specimens submitted for irradiation in the CP-5 reactor were found to have an average apparent density of 9.2 g./cc. and an average apparent porosity of 5.4%. The specimens submitted for irradiation in the M.T.R. reactor were found to have an average apparent density of 10.06 g./cc. and an apparent porosity of 1.3%. These pellets were encased in aluminum-1 wt. % nickel cans with the annulus filled with lead or gas. CP-5 burn-outs ranged from 0.19 a/o to 0.29 a/o of the total metal atoms. These specimens were intact but fragmented. A typical specimen is shown in Figure 3. This specimen had a burn-out of 0.29 a/o, and is shown after decanning.

M.T.R. burn-out ranged from 0.34 a/o to 1.25 a/o (Table 1). Surface heat flux was estimated to be 27×10^4 to 102×10^4 B.t.u./(hr.)(sq.ft.) central metal temperatures were estimated to range from 1,060 to 3,900° C. (melted).

Postirradiation examination revealed that dimensional changes (if any) were slight in the specimens in which the central metal temperature was estimated to be 2,000° C. or less. Some fragmentation had occurred in these specimens, but in general the condition of the slugs was good. A typical specimen is shown in Figure 4. Specimens irradiated to 1.25 a/o burn-out appeared to fail in two ways:

1) In the tests in which the annulus was filled with lead, the failure appeared to be due to gas pressure with subsequent hoop tensile stress fracture. 2) In the tests in which the annulus was filled with gas, the failure appeared to be due to melting of the clad.

Figure 5 shows a cross section of a specimen irradiated to 1.25 a/o of the total metal atoms (estimated central

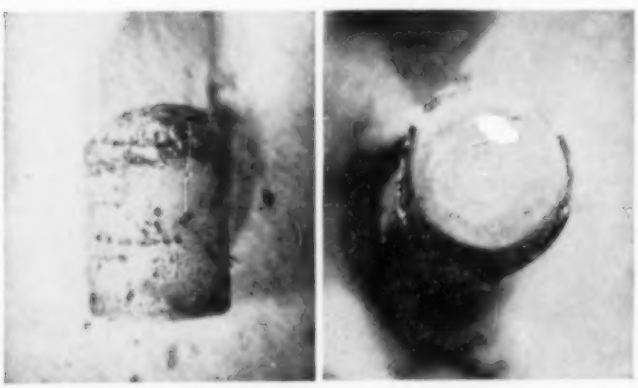


Fig. 3. Pellets after decanning operation. Left, top pellet. Right, bottom pellet.

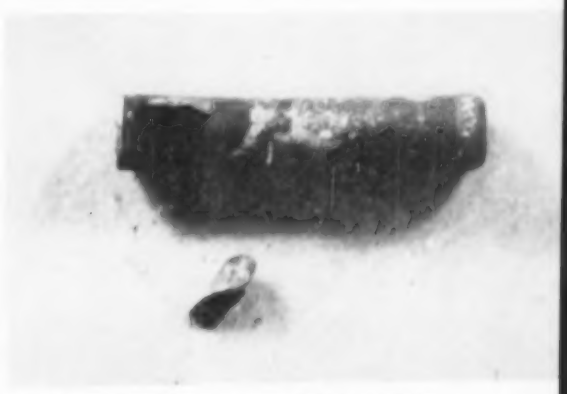


Fig. 4. Specimen CA-2-2 after removal of Al-Ni cladding.

Fig. 5. End view of specimen CA-4-2 with calculated central temperature of 3,900° C. showing evidence of central melting in the fuel.

Table 1.—Effects of Irradiation on Ceramic Fuel Specimens [a]

Specimen no.	Type of bonding [b]	Burn-up a/o metal	Fuel Temp., °C [c] center	Specific power cal./(sec.)(cc.)	Heat flux cal./sq.cm.
CA-1-1	Lead	0.34	1060	125	19.8
CA-1-2	Gas	0.34	1060	125	19.8
CA-2-1	Lead	0.64	2000	240	38.1
CA-2-2	Gas	0.64	2000	240	38.1
CA-3-1	Lead	1.10	3300	400	63.4
CA-3-2	Gas	1.10	3300	400	63.4
CA-4-1	Lead	1.25	3900	475	75.3
CA-4-2	Gas	1.25	3900	475	75.3

[a] All CA specimens were ThO_2-10 w/o UO_2.
[b] Gas bond consisted of welding gas (80% He, 20% A).
[c] All specimens were clad in 1% Ni-Al.

metal temperature of 3,900° C.) in which evidence of melting appeared.

These preliminary tests indicated that a thoria-urania solid solution fuel would be feasible, and that the ceramic material could be fabricated with little or no difficulty. The low thermal conductivity of the ceramic indicated a high central metal temperature, and in order to minimize this high central metal temperature, the fuel design was established as ¼-in rods. This diameter of ceramic was considered the minimum size which could be easily dry pressed.

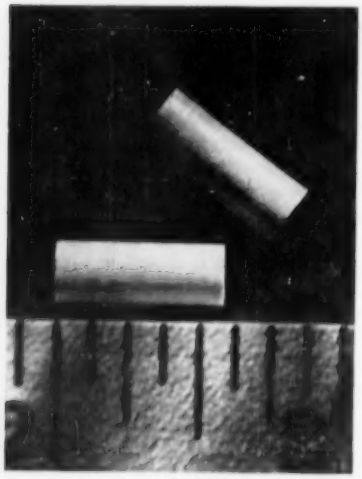


Fig. 6. Fired thoria pellets.

Fuel Fabrication

A brief review of techniques employed in the preparation of these ceramic fuel elements would be of interest to the chemical engineer.

The pressing mixture for the Borax IV elements consisted of 93.41 w/o ThO_2 and 6.59 w/o U_3O_8 of 90% enrichment, all of −325 mesh. After ball milling for 3 hr., the powder is dampened and forced through a 16-mesh screen to form granules, which are dried to a free-flowing powder at 80° C. Before pressing, a mixture of kerosene and oleic acid are added as lubricant. The pellets produced at 14,000 lb./sq.in. varied in length from 0.750 to 0.375 in., and the diameters from 0.267 to 0.270 in.

The pressed pellets were calcined in alumia crucibles at 260° C. to remove most of the organic binder, then fired to 1,750° C. in approximately 16 hr. The peak temperature was held for 2 hr., and the pellets were cooled in the furnace.

The fired pellets have an average geometric density of 8.3 g./cc. and an average apparent density of 9.8 g./cc., with diameters of 0.299 ± 0.002 in. This tolerance eliminated grinding to size, as 0.010 in. of lead was specified to fill the space between the pellet and the inside diameter of the enclosure tube. Figure 6 shows uniform appearance. Rejects due to imperfections averaged less than 4 per cent.

The fuel subassembly for Borax IV consists of six tube plates (8 tubes/tube-plate) spot welded into an assembly (see Figure 7). The fuel charge consists of 24-in. aluminum-nickel alloy (1 w/o Ni in 2S aluminum) of urania-thoria pellets lead bonded in place in each tube plate. Lead bonding was performed by dipping the loaded tube plates into molten lead maintained at 490-500° C. Figure 8 shows a cross section of one of the 6-unit fuel plates, along with the aluminum side plates.

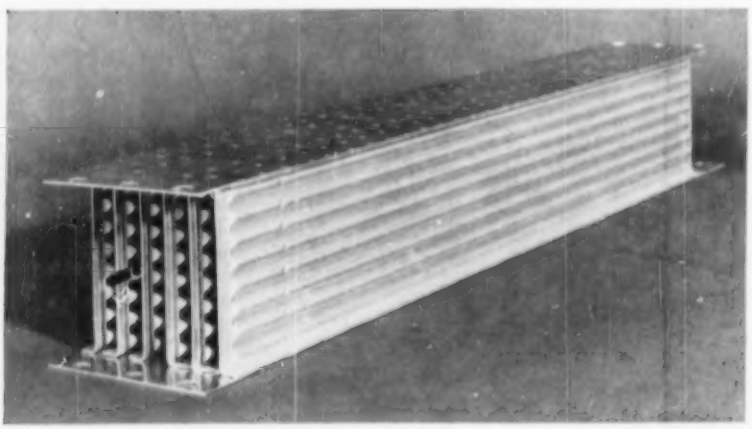


Fig. 7. Formed fuel plate assembly of six units.

Acknowledgment

The authors wish to express their appreciation to J. H. Kittle for the irradiation tests; to C. L. Hoenig, R. A. Bach, and R. C. Lied for their aid in fabricating the ceramic material; and to C. C. Stone, F. D. McCuaig, and D. E. Walker for their help in loading and assembling the fuel plates.

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To be presented at 1957 Nuclear Engineering and Science Conference, Philadelphia, Pennsylvania.

The refining of a number of uranium ores by solvent extraction of slurries produced by digesting the ore concentrate in nitric acid has been investigated and found amenable to producing uranium of reactor grade, with interesting economic possibilities. Various impurities in ores can greatly affect, by this process, product purity, product recovery, and refinery operations. The effect of these contaminants in uranium ores and concentrates from Colorado, Canada, and Australia have been under investigation. Refinery operational difficulties, also to be considered in scale-up, were indicated for (1) pumping and metering digest slurries with high solids content, (2) scale deposition in the processing equipment, (3) corrosion from halides in the nitric acid digest feed and raffinate liquors, and (4) excess loss of solvent in the raffinate stream.

REACTOR GRADE URANIUM by extraction of SLURRIES

D. S. Arnold and B. G. Ryle | National Lead Company of Ohio * Fernald, Ohio

The application of tributyl phosphate extraction of slurries to refining of uranium ores has been investigated from the standpoint of the effects of various constituents on product purity, product recovery, and refinery operations. The theoretical aspects of the tributyl phosphate extraction of uranium have been reviewed by Hahn (*2*). Sege and Woodfield (*3*) have reported a study of pulse-column operational variables for the extraction of uranium by tributyl phosphate from essentially pure uranyl nitrate—nitric acid solutions. Conclusions are based on small-scale batch countercurrent extraction tests and on pilot plant pulse-column extraction tests.

The Slurry Extraction Process

The uranium content of ore is first converted to uranyl nitrate by digesting the ore concentrate in nitric acid. The resulting aqueous slurry is adjusted to the desired concentration of uranium and nitric acid. The uranium is then extracted as the uranyl nitrate with a solution of tributyl phosphate in an inert kerosene diluent. By adjusting the feed and extractant flow rates through the primary extraction column (Figure 1), an organic extract stream which approaches uranium saturation for the solvent phase is produced. The uranium concentration in the raffinate stream is extremely low.

Tributyl phosphate, although selective, is not specific for uranium; therefore, other elements are extracted to a small extent. To remove these, the organic stream from the primary extraction column is passed through a second column where it is scrubbed countercurrently with deionized water. Here the flow rates are adjusted to remove practically all the impurities. Some uranium enters the scrub water at the same time. The effluent scrub stream is recycled to the primary extraction column in order to recover the uranium contained in it. The organic product stream from the scrub column at this state contains only spectroscopical quantities of T.B.P.-extractable and physically entrained impurities.

Reextraction with deionized water proceeds easily with essentially complete transfer of the uranyl nitrate from the organic phase in a third column.

The slurry-extraction refining process, as a whole, gives high over-all recoveries of the uranium present in the initial ore concentrates.

The uranium assay of the feed materials tested ranged from 0.5 to 75%. In the case of the high assay materials, those containing 35% uranium and higher, little difficulty was encountered with respect to recovery, product purity, and refinery operation. As the assay decreases, the concentrations of the impurities and the amount of nitric acid insoluble material in the ore increases and the difficulties in processing and meeting recovery and purity specifications also increase.

It is essential that a knowledge of the effects of various impurities on the system, and a prior evaluation of the extraction characteristics of the individual low-grade concentrate in the system be obtained before committing these feeds to the production plant.

Tests of a number of low-grade concentrates from the Colorado Plateau, Canada, and Australia, having assays ranging from 0.5 to 16% U, have greatly aided in an understanding of the problems involved.

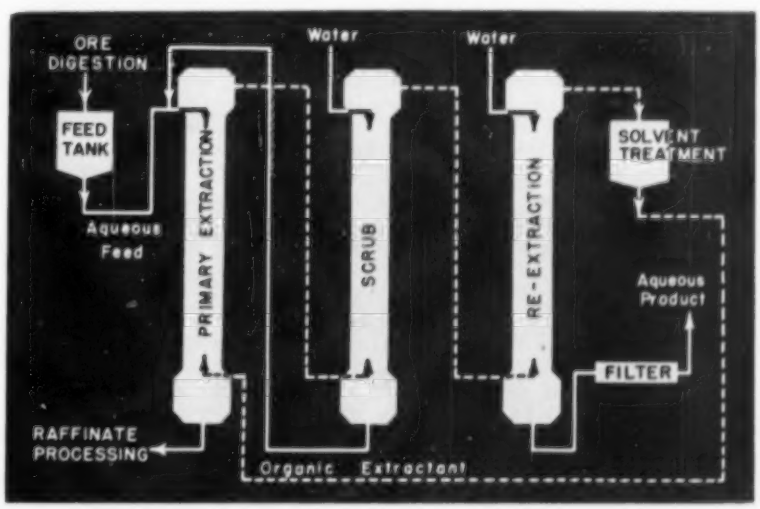

Fig. 1. Slurry extraction system: solid lines, aqueous; dotted lines, organic.

* Arnold and Ryle are Department Head and Supervisor, respectively.

Ore Impurities and Their Effects

Without reference to any particular feed material, this discussion will be concerned with the effects of the impurities found in various ores and concentrates upon the extraction system described and with the difficulties involved in processing these materials.

The major impurities normally encountered in low-grade uranium-bearing materials can be categorized into three groups depending upon their effects on (1) the physical extraction system, (2) the efficiency of the extraction process, and (3) the purity of the product.

SCALE-BUILDERS AND CORROSIVE AGENTS

Those impurities which affect the physical extraction system are the scaling agents and those ions which promote excessive corrosion in the nitric acid medium. Calcium sulfate tends to deposit on the walls and plates in the extraction column and hence would necessitate operational shutdowns for cleaning. A continuous scale build-up would result in changes in the column characteristics and a reduction in extraction efficiency. In extreme cases, scale deposition may extend to pipe lines and pumps. A second deposition of insoluble silicates has been noted during the processing of some concentrates. When this occurs, scale build-up proceeds rapidly and necessitates more frequent cleaning cycles.

Fluorides and chlorides in the presence of nitric acid present a serious corrosion problem in the digestion equipment and in the raffinate-processing and nitric acid-recovery systems (*1*).

INHIBITORS

A number of impurities, generally present in the form of anions, tend to reduce the efficiency of the extraction process. Predominant among these are sulfate and phosphate. When the concentration of these ions becomes too great, they preferentially associate the uranyl ion. Since uranyl sulfate and phosphate are not extracted by tributyl phosphate, the efficiency of the process is greatly reduced. The arsenate and vanadate ions also fall into this group. In extreme cases, considerable loss of uranium through the raffinate stream may occur.

URANIUM CONTAMINANTS

The last major group of impurities consists of those which directly affect the purity of the final uranyl nitrate product. These are carried through the refining process, either by coextraction with the uranium or by physical entrainment. They can be divided into four subgroups. Of primary importance are the elements of high cross-section for thermal neutrons. These elements therefore must be held to an absolute minimum in the final reactor fuel elements. These include boron, cadmium, the rare earths, lithium, arsenic, etc.

A second subgroup includes sulfur, phosphorus, carbon, chlorine, and fluorine all of which affect the physical structure of the uranium metal.

In addition, there is a large group of elements which have a special affinity for tributyl phosphate and its hydrolysis products and which follow the uranium through the extraction system. They are generally the elements which possess high oxidation states. Chromium, vanadium, thorium, zirconium, cerium, molybdenum, lead, ruthenium, palladium, zinc, tin, and silicon fall in this category.

The final subgroup is composed of those elements which form volatile fluorides — molybdenum, vanadium, ruthenium, and silicon.

COMBINATIONS

In the preceding discussion, the effect of each impurity has been treated independently of the others. Combinations of certain of these materials must be considered also. In some cases, certain of these ions combine to form ionic complexes, which in themselves are either extraction inhibitors or are in themselves extracted. In addition, the effects of these impurities are additive. Therefore, it can be seen that a preliminary evaluation of the extraction characteristics of each new low-grade ore concentrate must be evaluated in the laboratory and pilot plant before being approved for production processing.

Refinery Operational Difficulties

Refinery operational difficulties may be encountered in processing feed slurries of low-grade concentrates. As the uranium assay of the feed material decreases, there is an increase in the amount of nitric acid insoluble residues present in the feed slurry. The presence of these solids would increase the difficulties in pumping and metering the feed slurries to the column and the raffinates from the column and through the raffinate processing area. Considerable pump and valve erosion may occur necessitating frequent repairs and replacements. To reduce these difficulties to a minimum, blending with high-assay concentrates is desirable where possible.

Loss of solvent in the raffinate stream must be studied also. The loss due to the solubility of the organic extractant in the aqueous waste stream must be accepted since recovery of this material is not economically feasible. However, physical entrainment also occurs especially at high column throughputs and when feed slurries with high solid content are processed. To reduce this loss to a minimum, the raffinate stream may be washed with kerosene to recover the tributyl phosphate.

The behavior of these various impurities in the extraction system has been surveyed experimentally in the laboratory and pilot plant with various low-grade uranium concentrates. As a result of this type of investigation, it is possible (1) to establish a tentative maximum tolerable concentration for each of a number of these elements, and (2) to establish optimum process conditions for the refinery operation. It is evident that since there is an almost unlimited number of combinations of impurities possible, the specification on the feed materials must be reviewed and modified as new concentrates are received and evaluated.

In the primary extraction step, the uranium saturation in the organic product stream must be maintained as high as possible without uranium losses occurring in the raffinate stream. This reduces the coextraction of elements other than uranium to a minimum. Although a few of the impurities are removed more efficiently by scrubbing with cold water, it has been found that a hot scrub cycle gives a better over-all purity. Passing the aqueous product stream from the reextraction column through suitable polishing filters removes practically all the entrained solids and further increases product purity. It is essential that product contamination by physical entrainment through the extraction system be held to an absolute minimum.

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To be presented at 1957 Nuclear Engineering and Science Congress, Philadelphia, Pennsylvania.

Fig. 3. Recovery facility, main floor.

URANIUM RECOVERY

from aqueous wastes

Solutions derived from equipment cleaning at the Gaseous Diffusion Plant contain isotopically enriched uranium. The facility for recovering this uranium, processing it to an oxide, fluorinating the oxide to uranium hexafluoride is reviewed. Attention is given to design criteria which provide for nuclear safety.

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The uranium recovery facility at the Oak Ridge Gaseous Diffusion Plant by extraction methods removes and purifies the uranium contained in aqueous wastes. In succeeding steps, this uranium is processed to oxides and reacted with fluorine to uranium hexafluoride, which, as a final product, is refed to the gaseous diffusion cascade at the point of matching isotopic analysis.

Process equipment in gaseous diffusion service is subjected to continual deposition of uranium fluorides. Whenever this equipment is removed from the system, it is thoroughly cleaned. The solutions from this treatment contain uranium having a wide range of isotopic assay. They will probably also show high concentrations of impurities such as aluminum, calcium, copper, iron, magnesium, manganese, nickel, tin, and titanium.

Critical Hazards Considerations

A planned chain-reaction experiment depends upon the arranging of a supercritical mass of enriched uranium. It follows then that an accumulation of uranium under accidentally propitious conditions could be expected to cause some level of nuclear chain reaction. To avoid such a possibility in a recovery facility and with a minimum of reliance on operating procedures and personnel performance, a specialized geometry of critical hazards has been developed.

The basic configurations of this geometry are shown in Figure 1: (1) the 5-in. pipe, (2) the 1½-in. tank, and (3) the 8-in. sphere.

These configurations must be combined frequently in design applications. Examples are presented in Figure 2.

Since equipment items of these shapes and dimensions are "always-safe" only if isolated, there also must be interaction principles which control their relative locations within a system. A general mathematical expression of these principles is 8% of 4π, or one steradian. Derivation of this parameter assumed conditions of U^{235} assay, U^{235} quantity, and chemical form most favorable to a chain reaction.

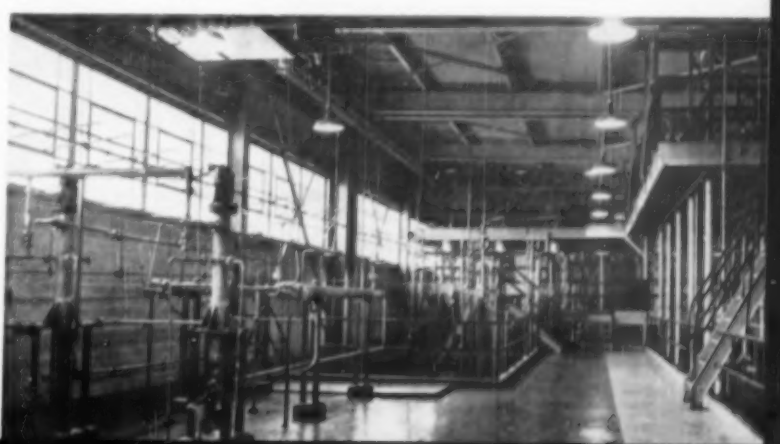
As would be expected, critical hazards considerations exert a major influence on the space requirements of an enriched uranium processing area. Photographs in Figures 3 and 4 show the relatively extensive facilities necessary to recover and process uranium to an oxide at the rate of 100 lb./day.

Solution Recovery Facility

The function of the recovery facility is to recover uranium from recycled cleaning solution and from miscellaneous waste solutions, all containing variable concentrations of impurities. In addition to the requirements for nuclear safety, the following criteria also served as bases for design:

1. Because of the value of enriched uranium, the design must provide for rigid accountability, with a maximum discard of 1 p.p.m.
2. The extraction system must be capable of recovering 100 lb./day of uranium from corrosive cleaning solutions.
3. Austenitic stainless steel and Heliarc welding must be used for equipment and piping throughout the facility.

Fig. 4. Recovery facility, mezzanine floor.



* Clouse is Assistant Area Supervisor; Dykstra, Area Supervisor; Thompson, Department Superintendent of Oak Ridge Gaseous Diffusion Plant.

These recovery operations are accomplished in two separate systems:

1. The Mixer-Settler system extracts uranium from equipment cleaning solution at a high flow rate, so that this solution can be promptly reused. The uranium concentration of the stripped solution is not required to meet discard specifications.
2. The General Recovery system is designed to remove uranium so thoroughly that the raffinate may be discarded.

Mixer-Settler System

This continuous process (Figure 5) employs two parallel vertical mixers designed to mix and extract uranyl nitrate from nitric acid cleaning solutions with an organic solvent. The average feed rates are 100 gal./hr. acid solution and 26 gal./hr. organic.

Typical recycled nitric acid cleaning solution contains 0.3 to 2.0 g. U/liter, with a pH of 0.1 to 0.4 and a sp. gr. of 1.3 to 1.4. The relatively high specific gravity required for phase separation is obtained by the addition of aluminum nitrate. The aluminum nitrate also serves as a fluoride complexing agent to reduce corrosion of stainless steel equipment. A normal organic solvent analysis would show 20% tributyl phosphate and 80% varsol mixture having a sp. gr. of 0.83.

The acid-solvent mixture flows by gravity to two parallel horizontal settlers where the phases separate by density difference. The raffinate from the settlers contains approximately 20 p.p.m. U and is returned to the equipment cleaning facility for reuse.

The uranium-bearing solvent and water are pumped countercurrent through a pulse-agitated stripper column, 3 in. by 27 ft. In this step the uranyl nitrate is transferred from the organic to the aqueous phase. The uranyl nitrate solution is concentrated then to 1.35 to 1.45 sp. gr., drum dried to dry uranyl nitrate hexahydrate, and converted to UO_3 and U_3O_8 in a calciner.

Typical operation data from the mixer-settler are presented in Table 1.

A photograph of the mixer-settler system is shown in Figure 6.

General Recovery System

This system (Figure 7) consists of two parallel lines with a total capacity of 10 lb. U/hr. Each line includes a preevaporator, an extraction column, a stripping column, a postevaporator, a drum dryer, and a calciner, all interconnected to form a continuous uranium recovery unit. Each line is designed to extract uranyl nitrate from nitric acid waste solution having wide ranges of uranium content, impurity concentrations, and specific gravities.

The preevaporators are designed to increase the uranium concentrations of the extraction column feed solution. A mixer agitated-type extraction column extracts the uranyl nitrate by countercurrent flow from the waste solution to meet the uranium discard specification. The contaminated organic from the extraction column flows by gravity to a mixer agitated-type countercurrent stripper column where the mass transfer of uranyl nitrate from the organic to the aqueous phase is effected. Uranyl nitrate from the stripper column is pumped to the postevaporators, where it is concentrated to a sp. gr. of from 1.35 to 1.45. The evaporator product is fed to a drum dryer to produce dry uranyl nitrate hexahydrate. This dry material is gravity fed to a calciner for thermal decomposition to UO_3 and U_3O_8.

Details of Process Equipment

EVAPORATORS

The steam-heated pre- and postevaporators (Figure 8) are designed to meet the criteria as given in Table A (page 69-F).

EXTRACTION COLUMN

The extraction column (Figure 9) is a mixer-agitated type countercurrent column, designed to effect the mass transfer of uranium from the nitric acid waste solution to the organic, with a solvent to acid feed ratio of approximately 1:1. This column is 19 ft. 7 in. tall and of 5 in. diam. The column is

Fig. 10. Agitator mixed extraction and stripper columns.

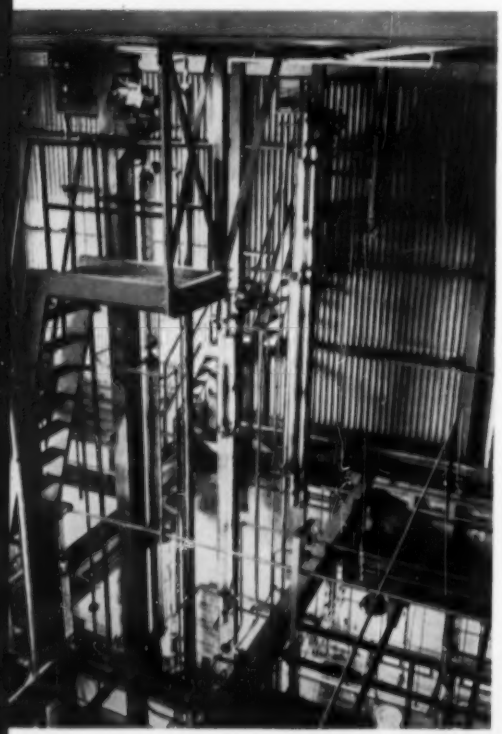


Table 1.—Mixer-Settler Operation Data

	Acidity (pH)	Uranium concentration of feed (p.p.m.)	Mixer feed solution (gal./hr.)	Organic (gal./hr.)	Stripped solution (p.p.m. U)	Efficiency * (%)
	0.3	1210	84	26	6.5	99.95
	0.3	1090	86	26	20.0	98.16
	0.2	890	72	26	15.0	98.31
	0.2	850	110	26	60.0	92.94
	0.3	880	114	26	70.0	92.04
	0.2	890	68	26	80.0	91.01
	0.2	630	94	26	7.0	99.99
	0.1	1040	92	26	5.0	99.52
	0.2	900	72	26	15.0	99.52
	0.3	1010	120	26	25.0	97.52
	0.2	1180	78	26	10.0	99.15
	0.2	1720	82	26	1.0	99.94
	0.2	1130	92	26	35.0	96.90
	0.2	890	110	26	8.0	99.10
	0.4	330	106	26	7.0	97.87
	0.2	990	94	26	30.0	96.96
	0.4	1170	106	26	4.0	99.65
	0.1	1000	130	26	20.0	98.00
	0.2	1230	112	26	6.0	99.51
	0.2	1770	110	26	20.0	98.87
	0.4	910	130	26	20.0	97.80
	0.4	1030	140	26	15.0	98.54
	0.3	670	100	26	5.0	99.25
	0.2	880	92	26	5.0	99.43
	0.4	1010	106	26	8.0	92.08
Avg.	0.25	1012	100.08	26	19.66	97.99

* Efficiency $= 100\left(1 - \frac{\text{uranium concentration of stripped solution}}{\text{uranium concentration of feed solution}}\right)$

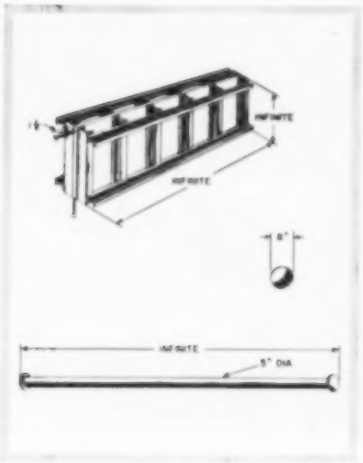


Fig. 1. Basic configurations.

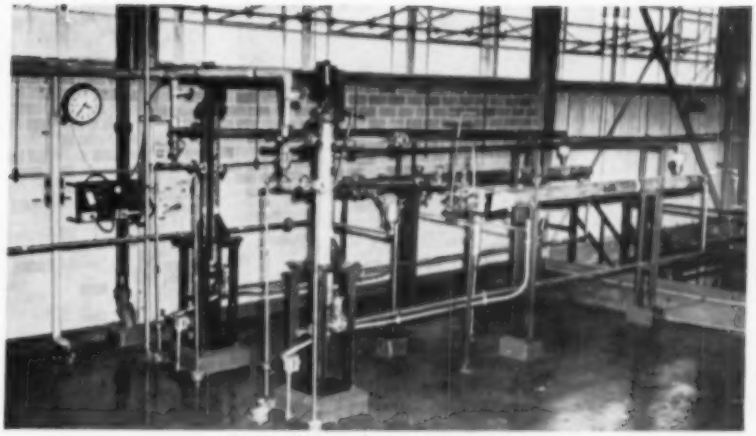


Fig. 6. Mixer-settler extraction system.

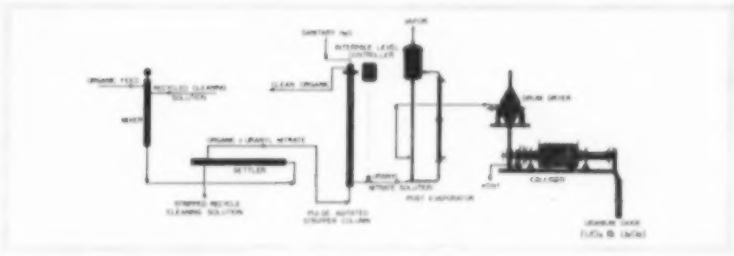


Fig. 5. Mixer-settler system.

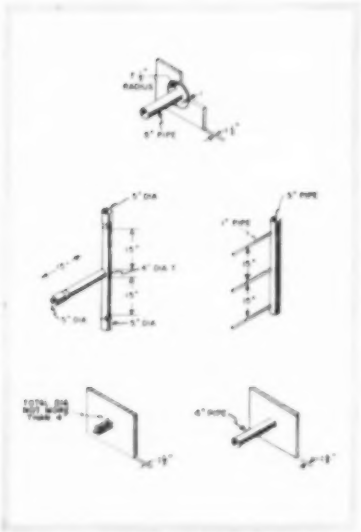


Fig. 2. Design application of configurations.

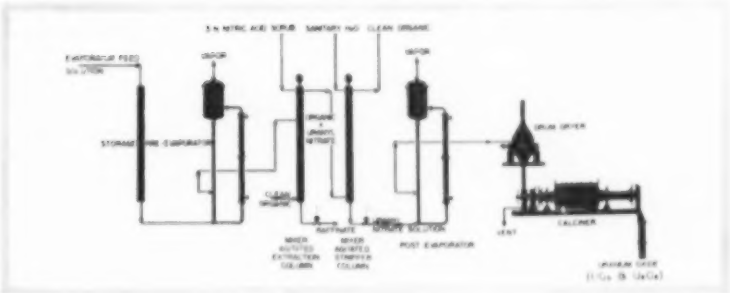


Fig. 7. General recovery system.

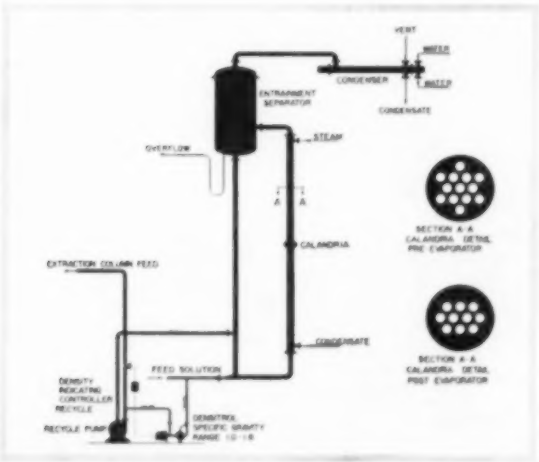


Fig. 8. Evaporators.

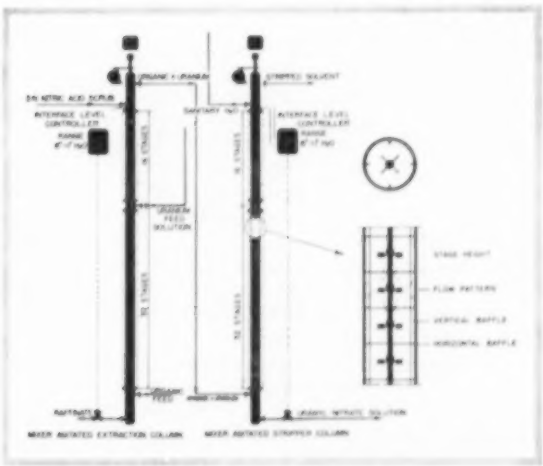


Fig. 9. Extraction and stripper columns.

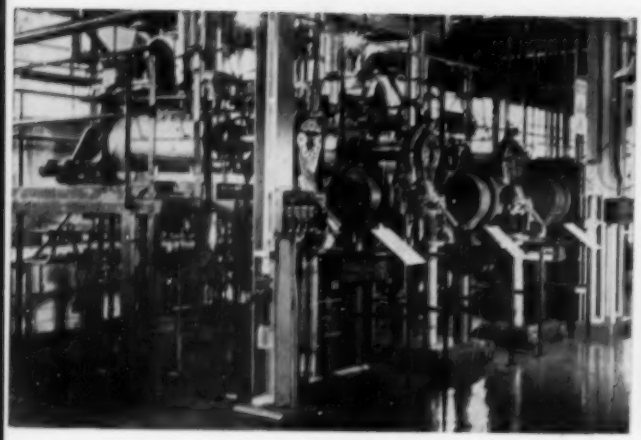


Fig. 11. Drum dryer and calciner.

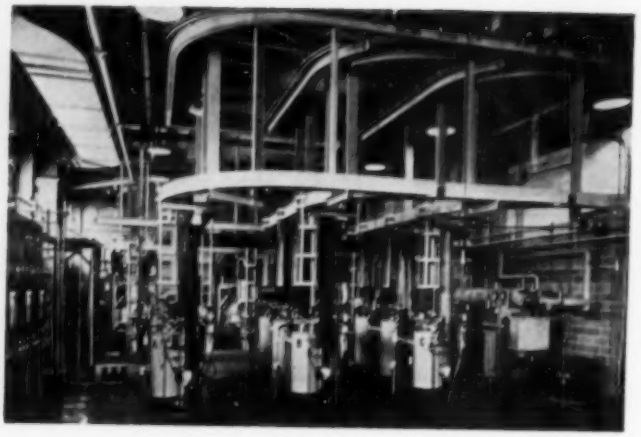


Fig. 12. Oxide fluorination system.

Table 2.—Typical Oxide Characteristics

Uranium (%)	Pack density (lb./cu.ft.	Bulk density (lb./cu.ft.)	Water (%)	Nitrate (%)	Spectrographic analysis (wt. %)								Sieve analysis (U. S. Standard Sieve No.)			
					Al	Ca	Cu	Fe	Mg	Mn	Ni	Si	+20 %	+20—40 %	+40—80 %	—80 %
79.1	195.41	149.83	0.04	0.00	0.05	0.2	0.20	0.5	0.20	....	0.5	...	16.70	24.70	34.30	24.40
71.4	180.46	84.28	0.12	0.15	0.20	0.2	0.10	0.5	0.10	....	1.0	...	0.00	0.11	22.08	77.81
76.0	162.94	89.89	0.06	0.00	0.20	0.5	0.05	0.3	0.10	....	1.0	...	0.00	0.10	9.90	90.10
80.9	128.60	87.40	2.10	0.01	0.50	1.0	0.20	0.3	0.20	0.05	0.3	0.1	0.02	0.04	1.44	98.50
79.8	177.93	121.11	0.11	0.68	0.10	2.0	0.30	0.5	0.20	....	1.0	...	0.10	11.00	34.60	54.40
79.8	216.00	146.71	0.00	0.04	2.60	0.5	0.01	0.1	0.02	....	1.0	...	1.70	17.50	23.70	57.10
77.1	101.76	86.81	0.51	0.29	....	0.3	0.02	0.3	0.02	....	0.3	...	3.20	12.40	29.20	55.20
80.7	220.38	141.09	0.04	0.05	....	5.0	0.02	0.1	0.02	....	0.6	...	4.30	7.30	10.30	77.90
77.1	179.17	107.38	0.00	0.32	1.00	1.0	0.02	1.0	0.02	....	1.0	...	7.20	21.00	26.00	45.90
71.9	161.69	96.77	0.00	0.20	0.30	0.6	0.14	1.0	0.02	....	1.0	...	0.00	0.90	28.90	70.20
62.9	127.98	81.78	0.00	1.75	1.00	2.0	0.02	1.0	0.02	....	1.0	...	0.40	4.00	31.80	64.30
68.7	158.57	88.65	0.06	0.58	0.30	1.0	0.04	2.0	0.02	....	1.0	...	0.10	6.40	31.90	61.70
													0.00	0.06	7.38	92.56

constructed of Pyrex pipe to facilitate operational control. Settling zones, fabricated from 24-in. lengths of 5-in. stainless steel pipe, are installed at the top and bottom of the glass column to effect phase separation.

The interior components of the column are machined to close tolerances. They consist of a shaft with agitators, and vertical and horizontal baffle assemblies. A ⅝-in. shaft, 20 ft. in length, is fitted with forty-eight flat-bladed mixers on 4-in. centers. The baffle assembly includes four vertical baffles at 90-degree intervals around the inner circumference of the column, and fifty-two circular horizontal baffles. The agitator assembly and the baffle assembly together form forty-eight vertically stacked stages, each stage consisting of two horizontal baffles and a centered mixer.

Two immersed air bubblers, positioned above and below the interface, automatically control the interface level by differential pressures.

A height equivalent to a theoretical stage value of 6 in. has been determined. This value depends upon normality and impurity concentrations of the feed solution, the solvent to aqueous feed ratios, and the agitator speed.

STRIPPER COLUMN

The stripper and extraction columns (Figure 10) are of identical design. This column effects the mass transfer of uranyl nitrate from the organic to the water phase with a solvent to water feed ratio of 1:1.

DRUM DRYER

A steam-heated, pan-doctored drum dryer is used to produce dry uranyl nitrate hexahydrate from solutions concentrated by the postevaporator. The drum, 12 in. long and 6 in. diam., is rotated by a variable speed drive for the selective control of retention time.

Typical operating conditions are as follows:

Product rate	4.05 lb./hr.
Steam pressure	24 lb./sq.in.gauge
Drum speed	9.5 rev./min.
Feed concentration	300 g./liter U

Fig. 13. Detail of oxide fluorination system.

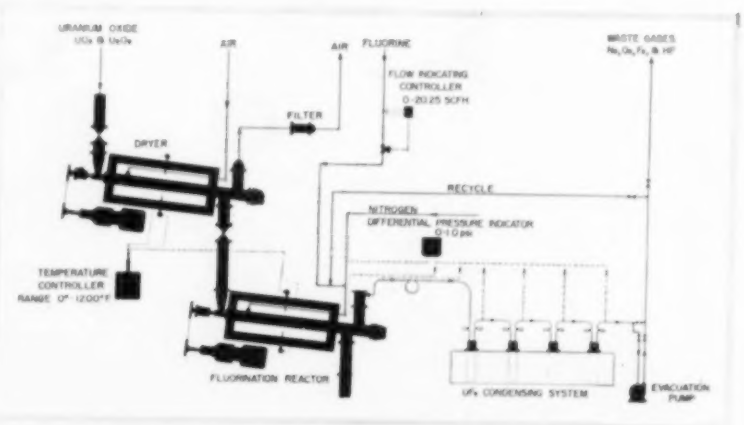


Table A.

	Preevaporator	Postevaporator
Feed rate lb./hr.	200	174
Vaporization rate lb./hr.	263	150
Feed temperature	70° F.	70° F.
Product properties		
Boiling point	225° F.	238° F.
Specific gravity	1.283	1.41
Viscosity	0.83 centipoise at 225° F.	0.50 centipoise at 238° F.
Design temperature difference between boiling solution and heating medium	60° F.	60° F.
Heat load B.t.u./hr.	299,000	173,000
Operating pressure	atmospheric	atmospheric

Both types of evaporators employ automatic density instrumentation which controls the product withdrawal at a selected specific gravity.

CALCINER

The drum dryer product is fed to an indirect fired rotary kiln calciner, 7 ft. long by 6 in. diam. (Figure 11), which thermally decomposes it to UO_3 and U_3O_8. The calciner capacity is 50,000 B.t.u./hr., with a controlled temperature range of 1,300 to 2,000° F. A 0-16 rev./min. variable speed drive and a slope changer permit control of retention time.

Typical product from this unit when operated at 1,400° F. with a feed rate of 8.2 lb./hr. and a retention time of 30 min. has a bulk density of 95 lb./cu. ft., a nitrate concentration less than 1%, and a water content less than 0.5%.

Oxide Fluorination System

The oxide fluorination system (Figure 12) consists of three parallel production lines capable of producing 4 lb. uranium hexafluoride/hr. by direct fluorination of UO_3 and U_3O_8. Typical physical and chemical analysis of the oxide processed in this unit are shown in Table 2.

PROCESS

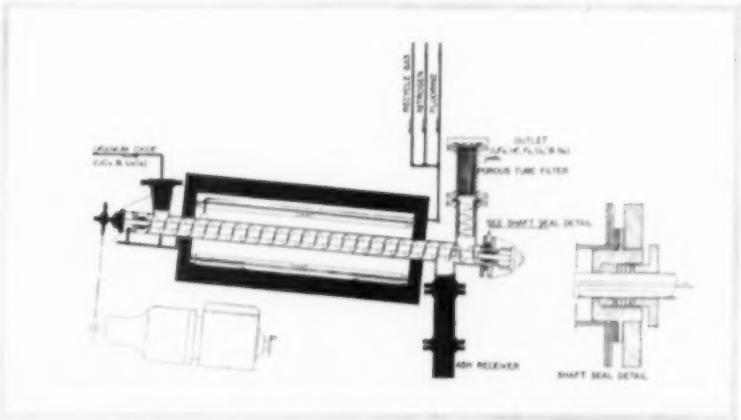
Batch processing of this oxide to uranium hexafluoride consists of three operations as shown in Figure 13: (1) drying, (2) fluorinating, and (3) condensing.

A 13-lb. charge of feed material is dried for 6 hr. at 900° F., with an 8-cu.ft./hr. dry air purge, in a screw-type dryer. Moisture removal improves fluorination efficiency, reduces corrosion, and eliminates uranyl fluoride plugs. The dry oxide is fed directly to a screw-type reactor and is treated at 1,050° F. with 98% fluorine at a maximum flow of 9 cu. ft./hr. at 0.5 lb./sq. in. gauge. The fluorine flow is regulated by means of a differential pressure instrument employing an orifice restriction. The following exothermic reaction occurs with a 95% yield:

$$2\,UO_3 + 6\,F_2 \rightarrow 2\,UF_6 + 3\,O_2 + 3{,}370\ \text{B.t.u./lb. } F_2$$

$$U_3O_8 + 9\,F_2 \rightarrow 3\,UF_6 + 4\,O_2 + 3{,}480\ \text{B.t.u./lb. } F_2$$

Fig. 14. Dryer and reactor detail.



URANIUM RECOVERY

After a retention time of 6 hr., the residual ash is removed and weighed to obtain a uranium material balance. The reactor outlet gases, uranium hexafluoride, fluorine, oxygen, and nitrogen are piped to a series of four chilled product cylinders, where the uranium hexafluoride is collected as a solid. The waste gases, containing less than 1 p.p.m. uranium, are vented to the atmosphere.

EQUIPMENT DETAILS

Dryer and Oxide Fluorination Reactor

The screw-type stainless steel dryer and the Monel reactor (Figure 14) are of identical design. Both the dryer and reactor are fabricated from five foot lengths of 4-in. schedule-40 seamless pipe. A 3-in. pitch cut-flight screw, supported at each end with a packing box, conveys and agitates the powder. The oxide retention time is controlled by varying the screw speed and by adjusting the reactor slope. The reactor and dryer are enclosed in electric furnaces with a capacity of 6.5 kw.

Table B.—Oxide Fluorination Cost
($/lb. of uranium)

Direct labor	$2.16
Maintenance labor	2.49
Fluorine	2.99
All other materials	2.22
Total cost	$9.86

Condensing System

The condensing system consists of four 5-in. diam. cylinders of 0.31 cu. ft. vol., connected in series, and partially immersed in a trichloroethylene bath. The fourth cylinder, which is baffled to provide maximum heat transfer, freezes out the final traces of uranium hexafluoride; thus loss to the atmosphere is prevented.

The trichloroethylene baths are designed to operate at —70° F., with a heat load of 17,130 B.t.u./hr. Refrigeration is supplied by a 2.5 ton Freon 22 compressor.

Cost Summary

Average operating costs, excluding overhead and depreciation, are tabulated in Table B.

To be presented at 1957 Nuclear Engineering and Science Congress, Philadelphia, Pennsylvania.

New processes promise more economic

FISSION PRODUCT REMOVAL

S. Lawroski and W. A. Rodger | Argonne National Laboratory, Lemont, Illinois

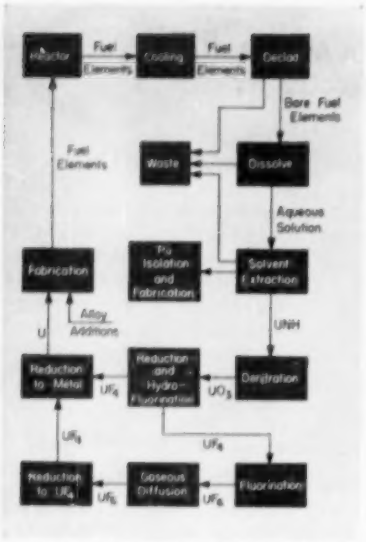


Fig. 1. Solvent extraction fuel cycle for natural uranium fuel.

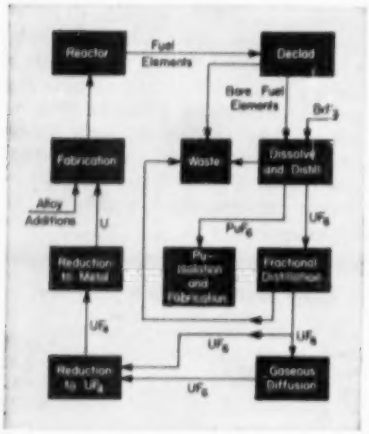


Fig. 2. Volatility fuel cycle for natural uranium fuel.

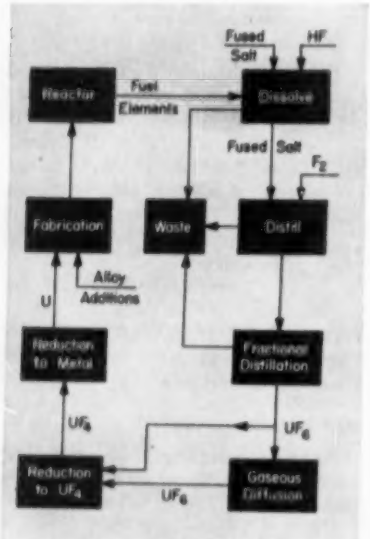


Fig. 3. Volatility fuel cycle for enriched uranium-zirconium fuel.

In the consumption of nuclear fuels in a reactor core or in the production of new nuclear fuels by transmutation in a reactor core or blanket, the operation under the present status of reactor technology is normally interrupted after only a small fraction of the desired reaction can take place, whether it be fission or transmutation. As a result, several cycles of these incomplete operations in a reactor, and intervening recovery and purification operations, are necessary to obtain what would correspond to the complete utilization of fissionable or fertile constituents.

Reactor fuel materials have to be reprocessed for one or more of the following reasons: (1) to add fissionable material, (2) to restore the heat transfer and structural properties of solid fuel elements which deteriorate owing to the destruction of the lattice structure by the fission process, (3) to recover bred fissionable material.

Because the separation cycle must be repeated, it must be capable of high yields and low cost per cycle. The process should accomplish this with a minimum of hold-up time to avoid excessive and hence costly inventories of fissionable material. Since some of the metals often included as cladding or diluents in fuel fabrication are appreciably expensive, it would obviously be desirable to have this process also recover these materials in an economic manner. The required degree of purification of fissionable and fertile materials from fission products may vary over a substantial range. For example, in the case of homogeneous reactors or those heterogeneous reactors where remote refabrication may be practicable, it is generally conceded that removal of important fission products by a factor of about 10 would suffice. On the other hand, when it is necessary to handle the fuel directly for refabrication purposes, the required decontamination from fission products may be as much as 10^7 fold or more.

Since fissionable materials are expensive, product losses must be kept as low as possible. Recoveries of greater than 95% are required and 98% or better are usually obtained. The more cycles that are required to obtain complete utilization of the fuel, the lower must be the loss if an economic cycle is to result.

Both the chemical and physical features of a processing scheme are profoundly affected by the character of the fuel, including the clad, alloying materials, and the geometry of the fuel itself. Since it is necessary to separate the valuable material from the broad spectrum of fission product elements and often from alloying elements as well, the chemistry of selected processes becomes complex.

The complexity of the fuel cycle can be illustrated by presently used processes. Some possible simplification on this cycle will be discussed in the light of current development work.

Present Fuel Cycle

Figure 1 illustrates the fuel cycle for a heterogeneous reactor employing solvent extraction. Discharged aluminum clad natural uranium fuel elements are first cooled, declad chemically, dissolved in nitric acid, and put through a solvent-extraction process which separates decontaminated uranium and plutonium as aqueous solutions. Each of these product solutions must be converted to metal through a series of steps. The metal is in turn refabricated and returned to the reactor or put to other uses. At various stages of the process, waste solutions are formed as indicated. This results in a lengthy process which, although it meets product specifications well, leaves at least some room for improvement in the area of economics.

Existing equipment for this process is made of stainless steel. Use of unmodified existing facilities is limited therefore to those fuels compatible with the system nitric acid-stainless steel. As reactor designers strive for higher and higher fuel integrity, the tendency is to add alloying agents and cladding materials which are not directly dissolvable in nitric acid or in other media which can be held in stainless steel. It is sometimes possible to handle certain reactor fuel changes by the introduction of a mechanical decladding operation or a chemical head-end step. But in other instances, completely new processes and equipment must be devised in order to handle new systems.

To date there has been relatively little multiple recycling of reactor fuel and the amount of burn-up has been low. The use of existing thermal re-

actors results in the formation of some U^{236} by neutron capture on U^{235}, and the production of Pu^{239} from U^{238}. The production of other higher isotopes is low at low burn-up values.

If, however, the fuel is carried to higher burn-up either in a single or in multiple passes, the situation becomes more complicated as illustrated in Table 1. Not only is neutron economy adversely affected, but significant quantities of U^{237}, Np^{237}, Pu^{238}, Pu^{240}, Pu^{241} and Am^{241} begin to appear in addition to U^{236}.

The presence of the 6.75-day U^{237} will increase somewhat the required cooling time to obtain a nearly completely decontaminated uranium product. The additional cooling may, of course, be added either before or after processing, but in either case, it increases the inventory costs.

The 90-year Pu^{238} and 6,300-year Pu^{240} will carry through with the plutonium product. Each isotope has high energy alpha particles which give an (α, n) reaction with fluorine atoms during certain stages of the isolation process to produce a higher neutron background. This is in addition to their spontaneous fission contribution of neutrons.

As neptunium and americium isotopes build up, their process chemistry becomes of importance. Finally, all these isotopes plus most particularly the U^{236} act as inert diluents so that at the alloy-addition step it becomes harder to get the required percentage of fissionable isotope into the element.

Possible Simplification Based upon Volatility of Uranium Hexafluoride

Three alternative processes demonstrate the manner of resolution of some of the chemical problems introduced by alternative fuel elements. They do not, however, get around the problems raised by the build-up of higher isotopes.

Figure 2 represents a fuel cycle in which the separations process is based upon the production of volatile compounds of uranium and plutonium which are decontaminated by fractional distillation or sublimation. The fuel element is decanned without extended cooling and dissolved in an interhalogen compound producing uranium hexafluoride which is decontaminated by fractional distillation. Plutonium is removed with fluorine at high temperature as PuF_6 and recovered as PuF_6 or, more likely, as PuF_4 since the reduction of PuF_6 to PuF_4 occurs readily. The decontaminated uranium hexafluoride may be sent directly to a gaseous diffusion plant or reduced to UF_4 and thence to metal, resulting in a considerable saving of process steps. This process has not yet been completely developed, but portions of it have been satisfactorily demonstrated in pilot plant stage. This particular scheme assumes a natural uranium element in any one of several clad materials.

Nearly all the highly enriched fuels considered or in use contain high percentages of alloy constituents and will not dissolve in liquid interhalogan compounds nor will they dissolve in nitric acid. An example is the zirconium matrix fuel. Figure 3 illustrates an alternative to the interhalogen process in which the fuel element is dissolved in a fused fluoride salt at elevated temperature. Anhydrous HF is used for dissolution ($U \rightarrow UF_4$) followed by fluorine (to take $UF_4 \rightarrow UF_6$). The UF_6 is decontaminated by fractional distillation. With these fuels, the production of plutonium is inconsequential so that its recovery is unnecessary. This type of process is being studied on pilot plant scale at two sites.

Possible Simplifications Based on Pyrometallurgical Processes

Figure 4 represents perhaps the ultimate in possible process simplification. In such processes it is envisaged that the fuel will be taken from the reactor and melted without extended cooling, perhaps with the use of its own radioactive heat for melting. A small fraction of the fission products, perhaps only half, would be removed by slagging and by volatilization. The fuel would be recast then into its final form for reinsertion into the reactor. This is, of course, a highly idealized statement of the problem. In all probability alloy additions and perhaps a remelt operation would be required. Clearly such a process would pose new and difficult problems for the refabricator since it is clear that this type of process will never produce a high enough degree of decontamination to allow contact metallurgy. Therefore, metallurgical refabrication processes must be extremely simple. This probably means that it will be difficult to incorporate metallurgical processes more complicated than, say, casting, and it will also probably require that the reactor designer be content with relatively simple shapes. These are admittedly difficult problems but the degree of simplification of the fuel-processing cycle is obvious. It should be noted that the development of some degree of remote metallurgy may be required anyway as burn-ups increase.

Along with this type of process, work is being done also on processes for the handling of blanket materials,

Table 1.—Nuclear Reactions After 25% Burn-up

Fuel: natural uranium — Burn-up: 25% of U^{235}

Neutrons: thermal — Basis: 100 neutrons

$NV = 10^{14}$ n./(sq.cm.)(sec.)

$$_{92}U^{235} + 42.5_0n^1 \longrightarrow FP + E + 105_0n^1$$

$$_{92}U^{238} + 7.0 \longrightarrow {}_{92}U^{239}$$

$$_{92}U^{239} + 0.03_0n^1 \longrightarrow {}_{92}U^{237} \xrightarrow{\beta^-} {}_{93}Np^{237}$$

$$_{92}U^{238} + 36.4_0n^1 \longrightarrow {}_{92}U^{239} \xrightarrow{\beta^-}$$

$$_{93}Np^{239} \xrightarrow{\beta^-} {}_{94}Pu^{239}$$

$$_{93}Np^{237} + 0.001_0n^1 \longrightarrow {}_{93}Np^{238} \xrightarrow{\beta^-} {}_{94}Pu^{238}$$

$$_{94}Pu^{239} + 9.1_0n^1 \longrightarrow FP + E + 26_0n^1$$

$$_{94}Pu^{240} + 3.8_0n^1 \longrightarrow {}_{94}Pu^{241}$$

$$_{94}Pu^{241} + 0.5_0n^1 \longrightarrow {}_{94}Pu^{242} \xrightarrow{\beta^-} {}_{95}Am^{242}$$

potential neutrons per cycle = 31

in which bred fissionable material is separated from the blanket material by a liquid metal extraction.

Conclusion

It should be clear that that reactor cycle is best which produces the most economical over-all fuel cycle. Therefore, a much closer degree of cooperation will be necessary between the reactor designer, metallurgist and chemical engineer.

Acknowledgment

The authors wish to thank M. Levenson for his constructive suggestions in the preparation of this paper.

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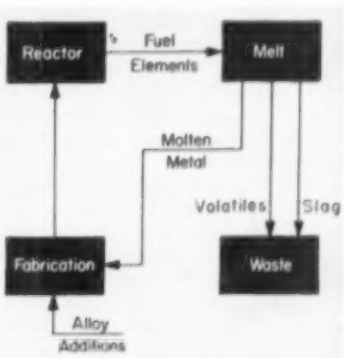

Fig. 4. Fuel cycle based on pyrometallurgical processing.

DECONTAMINATION

of irradiated uranium by a FLUORIDE VOLATILITY PROCESS

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A series of six pilot plant runs has been made on 10 kg. lots of uranium to demonstrate the decontamination of irradiated uranium by a process based on distillation of UF_6. A rough distillation followed by a purification distillation gave a decontamination factor of the order of 10^6 for the uranium hexafluoride product.

A fluoride distillation pilot plant has demonstrated the effectiveness of fractionation as a method for decontaminating uranium hexafluoride from mixed fission-product fluorides. Dissolutions up to 30 lb. U metal in liquid bromide trifluoride were conducted in a completely controllable manner. Uranium hexafluoride thus produced is decontaminated to an activity level well below that of old, natural, unirradiated uranium. A fission-product decontamination factor of the order of 10^6 is obtained by this process.

Distillation processing methods can be applied also to *enriched* fuels by means of a fused salt dissolution. Because of corrosion in the dissolver, low carbon nickel, high nickel alloys, and graphite have been investigated and found promising as materials of construction.

UF_6 is a particularly important compound for reactor fuel processing. It is used as feed to the isotope separations process. It may be reduced (via the tetrafluoride) to metallic uranium without any intervening aqueous processing steps.

BrF_3 liquid is used as the fluorinating agent rather than gaseous fluorine since the highly exothermic reaction makes the latter method difficult to control. BrF_3 dissolution is controllable as long as the uranium metal is immersed in the liquid phase. Table 1 gives the pertinent reactions and physical properties which form the basis of the volatility separations process.

In addition, decladding of the slugs and removal of the nonvolatile-fission products are involved. Any number of process schemes could be used to carry out these operations. The methods used are outlined in the flowsheet in Figure 1.

Further discussion of the properties of fluorides involved as well as the basic features of fluoride volatility processes may be obtained (*1,2,4*).

Process Steps in Pilot Plant

In Step I the uranium slugs are charged to the empty dissolver. These slugs are in aluminum cans, as reactor fuel elements. As aluminum does not react with BrF_3, this cladding is removed with aqueous caustic.

In Step II the BrF_3 solution is added. This solution may contain a few per cent of UF_6 and BrF_5 since in general this material is recycled from a previous separation. The UF_6 content has the desirable effect of increasing the rate of dissolution. The dissolution in this step is conducted at about 120°C. and at a total pressure of about 2 atm. In standard runs, some volatile products of the reaction are taken overhead from the dissolver to maintain constant pressure and approximately constant composition in the dissolver. This tends to keep the reaction rate uniform throughout the dissolution. This material was taken overhead as vapor from the head of the (packed) dissolver column.

In Step III the bromine produced in the dissolution is regenerated by adding fluorine gas. This reaction goes smoothly and rapidly at room temperature. (The fractionation of UF_6-BrF_3 mixtures is in general simpler than UF_6-Br_2 mixtures because of the low relative volatility and the high degree of nonideality of the latter.)

In Step IV the dissolver solution is fractionated. First there is taken overhead a small fraction containing noncondensables and the bulk of any highly volatile fission products. This material is sent to the scrub tower for waste disposal. Second the UF_6-BrF_5 fraction is taken overhead as charge to the purification column. Third all the residual bromine trifluoride is distilled out of the dissolver for subsequent recycle use. The charge to the purification column is fractionated to give a BrF_5-UF_6 recycle cut, a UF_6 product cut, and a BrF_3-UF_6 residue cut for recycle. The columns are operated with vapor take-off at about 3 atm. constant pressure.

The nonvolatile fission products remain as a dry residue in the dissolver; they are removed with an aqueous aluminum nitrate wash.

Corrosion in Fluoride Process Solution

Several metals may be used as materials of construction for bromine trifluoride process solutions, as described in a recent report (5). However, for the over-all process used here, nickel and Monel are most satisfactory. Corrosion rates obtained in the pilot plant are shown in Table 2.

Equipment

The pilot plant equipment is designed in accordance with the flowsheet (Figure 1) to handle 10 kg. batches of irradiated uranium. An equipment schematic is given in Figure 2.

A Monel dissolver of 90-liter capacity is provided for reasons of safety with external water cooling coils bonded to the vessel wall with copper spray metal, as shown in Figure 3. Steam is used in the coils for heating; all other process heating is electrical.

To enable use of dissolver as a still pot, a conversion is made on its top, through valves, to a 1.75-in. I.D. distillation column with a 9-ft. section packed with nickel (0.24 in. × 0.24 in.) Cannon Protruded Packing.

At the top of the column is a reflux condenser with connection to an overhead vessel to receive the distillation product.

A second (purification) column unit consisted of a 53-liter still pot with electric resistance heaters bonded to the wall with copper spray metal. The packed section of this tower was 1.75 in. I.D. and 16 ft. long, the packing being Helipak (3019). Tests with *n*-heptane-*iso*-octane indicated an H.E.T.P. of 2.0 in. In Table 3 are given the results of a column test with a BrF_5-UF_6 mixture, showing an H.E.T.P. of about 8 in. or an H.T.U. of 6 in. Definitive distillation studies of these mixtures have yet to be made. The emphasis in the work described here was on dissolution and decontamination. Earlier work at Brookhaven (*4*) has shown similar results with 2-in. continuous columns. High purity UF_6 product was obtained from UF_6-BrF_5 mixtures.

Material accounting in connection with charging and discharging of the various process units is by weight. Each column overhead product receiver is a weigh tank with the use of a remote head scale. In addition there are two 90-liter storage and transfer weigh-tanks, used with the dissolver. Another weigh-tank serves the still pot.

Fluorine addition was followed by observing pressure drop in either of two 17.6 cu.ft. steel storage tanks. A manifold system permitted either of these two tanks to be filled from standard 6-lb., 400 lb./sq.in. shipping cylinders.

Lines were welded except for connections to vessels themselves and to process valves, which used gasketed joints and standard 150-lb. flanges. Most liquid lines were ⅜-in. O.D. nickel tubing although some ½- and 1-in. pipe also was used. The smaller lines used ½-in., and the larger used 1-in. valves and flanges. Gaskets were a spiral-wound Flexitallic type, seating on smooth-faced flange surfaces.

Process valves were Monel packless type*, with a bellows seal with pneumatically operated stem. The valve was a simple shut-off type with a Teflon seat gasket and a machined seat integral with the body. Similar valves of smaller size† (¼-in.) and manually operated were used on the sampler system. A slug chute for the dissolver was closed with a 2-in. lift-plug valve actuated by an extension handle. The end of the slug chute was flanged and gasketed.

Each vessel was equipped with a thermowell for temperature indication and with a Monel bourdon-tube-pressure transmitter for pressure indication.

All lines were traced with nichrome heating wire and insulated to keep temperatures above the 64° C. solidification point of UF_6. The fractionation columns were kept adiabatic by controlling heating mantles to give zero temperature differential across a layer of insulation.

Safety features included: (1) leak

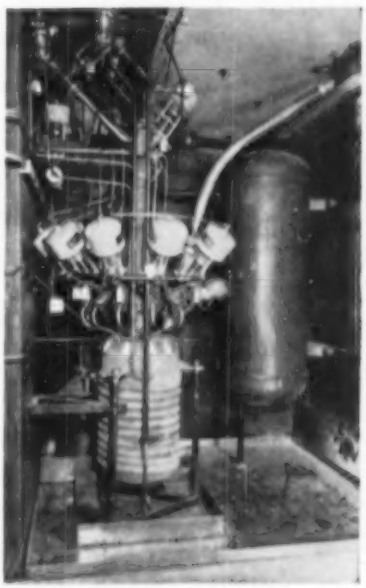


Fig. 3. Dissolver installed (before insulation).

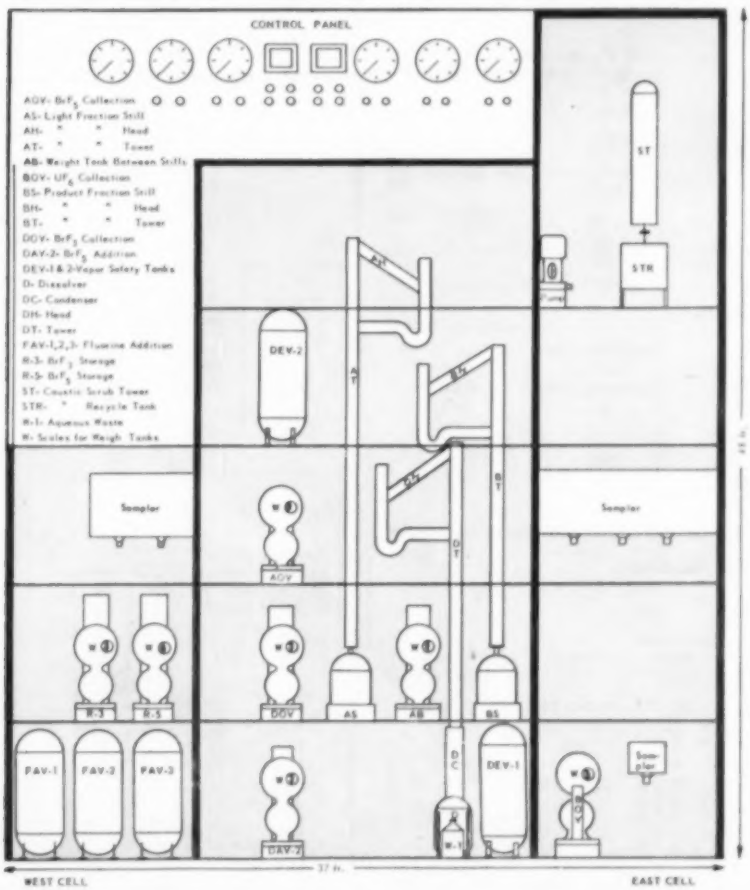


Fig. 2. Volatilization pilot plant equipment layout. View of center cell, section through cell bank.

* Model No. 3064, Fulton Syphon Division, Robertshaw-Fulton Controls Company.

† Model 1197, Hoke, Inc.

detector on each valve bellows, (2) rupture disc on each process vessel, (3) emergency cooling system on the dissolver, actuated by either temperature or pressure set point, and (4) interlock on still pot heaters, shutting them off in case of water failure.

In addition, two spray towers were employed: a process scrubber to dispose of interhalogen vapors by hydrolysis and neutralization in 10% potassium hydroxide, and a similar but much larger unit used to scrub all ventilation air from the equipment area to remove halogen resulting from any leakage of the equipment. Scrub tower operation has been described elsewhere (*3*).

The process equipment was mounted in previously installed concrete shielded cells. All process equipment, including shielding walls and four personnel access areas for sampling (except the ventilation exhaust air scrubber), was contained in a volume $10 \times 36 \times 40$ ft. high. Instruments and controls were centralized on panel boards mounted on top of the cell structure.

Table 2.—Corrosion of Nickel, Monel, and Inconel in Pilot Plant Dissolver

Metal	Penetration * mils	Comments
Liquid submerged coupons		
Unwelded Monel	0.7 to 0.8	Appearance: sound, no pitting
Unwelded nickel	0.6 to 1.0	Sound; some minute pits
Welded Monel-nickel	0.7	Small scattered pits
Unwelded Inconel	2.7 to 2.8	General attack, pitting
Welded Inconel	8.9	Attached and pitted; particularly the edges
Vapor exposed coupons		
Unwelded Monel and nickel	0.3 to 0.4	Good appearance
Welded Monel and nickel	0.4	Good appearance
Welded Monel-nickel	0.3	Good appearance
Unwelded Inconel	6.9 to 7.9	Severe attack; edges pitted
Welded Inconel	5.8	Attacked and pitted; weld thinned

* 600 hr. in halogen medium (15 to 160° C.)
25 hr. in aqueous wash and deconning medium (15 to 60° C.)

Table 3.—Batch Distillation of a Uranium Hexafluoride-Bromine Pentafluoride Mixture

Charge
- Total still pot charge ..... 67.3 lb.
- UF_6 content of charge ..... 37 wt. % (balance BrF_5)

Operating conditions
- Pressure ..... 50 lb./sq.in.abs.
- Still pot temperature ..... 90° C.
- Column temperature ..... 80° C.
- Boil-up rate ..... 22 lb./hr.(BrF_5)
- Reflux ratio ..... $27/1 = \frac{V}{D}$
- Pressure drop ..... 25 in. water (16-ft. column)
- Start-up time ..... 4 hr.

Column data
- Height packed section ..... 16 ft.
- I.D. ..... 1.75 in.
- Packing ..... Helipak 3,019

Separation Results

Overhead during distillation

cumulative amount (lb.)	grab sample composition (wt. % UF_6)	still pot composition (wt. % UF_6)	height equivalent to a theoretical plate (in.)	H.T.U. (in.)
6.4	0.236	37.1	...	8.8
16.8	0.037	40.0	8.3	6.4
27.1	0.058	62.9	7.7	6.1
32.6	0.093	71.3	8.0	6.2

Table 4.—Summary of Dissolutions

Run No.	Dissolver charge: Uranium (BrF_5, BrF_5UF_6) (lb.)	Solution (lb.)	Mole % UF_6 in sol'n: initial	final	Dissolution time (hr.)	Temp. (° C.)	Pressure lb./sq.in.abs.
D-1	7.7*	182	0.0	2.5	31	125 → 132	20 → 45
D-2	7.6*	167	2.9	5.0	8	110 → 122	38
D-3	22.8*	168	2.4	3.0	9	120	30
D-4	8.4*	233	3.7	5.1	9	120	40
D-5	5.2†	200	2.3	3.7	8	120 → 140	25 → 50
D-6	30.6*	209	4.6	3.7	14	120	38

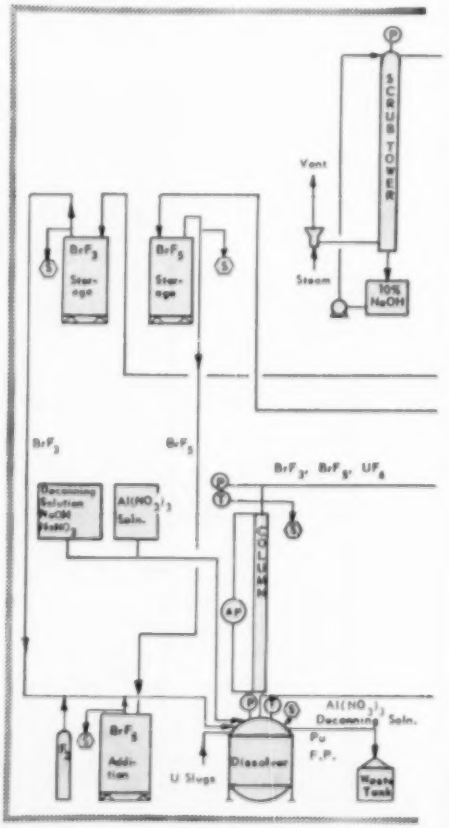
* Slugs 1.35-in. diam.
† Slugs 1.10-in. diam.

Sampling and Analysis

Samples were taken under their own vapor pressure to a reservoir from the liquid and vapor phase of each vessel and from the line carrying the overhead vapor stream from the column head to the overhead product receiver. The liquid was returned to the vessel by heat pressurizing of the reservoir. Sample tubes were ¼ in. Fluorothene tubes with standard flare connections.

Preparatory to analysis, interhalogen samples were hydrolyzed in 1.6 M nitric acid or water and hydrazine with a technique described elsewhere (*6*).

Bromine determinations were made by a Volhard titration or by a nephelometric method, the method depending on concentration. Uranium determinations were done by an X-ray



spectroscopic method; fluoride by fluosilicic acid distillation followed by lead bromofluoride precipitation.

Pilot Plant Runs

DISSOLUTION OF URANIUM SLUGS IN BrF_5

Results of six dissolutions are summarized in Table 4. In a run, two to six slugs of uranium are charged to the dissolver. The dissolver solution then is introduced in a quantity sufficient to insure that the slugs be covered with liquid at all times. The temperature of the dissolver then is raised to start the reaction. A small amount of water cooling is used to control the temperature.

The first three runs were made with inactive uranium. The slugs used were reactor-grade normal uranium (as rolled, not heat treated) and were 1.35 in. in diam. and 4 in. long, unclad and weighing approximately 3.5 lb. each.

The last three runs contained activity from irradiated normal uranium slugs.

In run D-1, the dissolver was operated as a closed system, with no product take-off during dissolution. The BrF_3 charged to the dissolver initially contained about 7 mole % BrF_5* and no UF_6. The initial dissolution rate was slow, the slowness necessitating raising the temperature to 132°C.

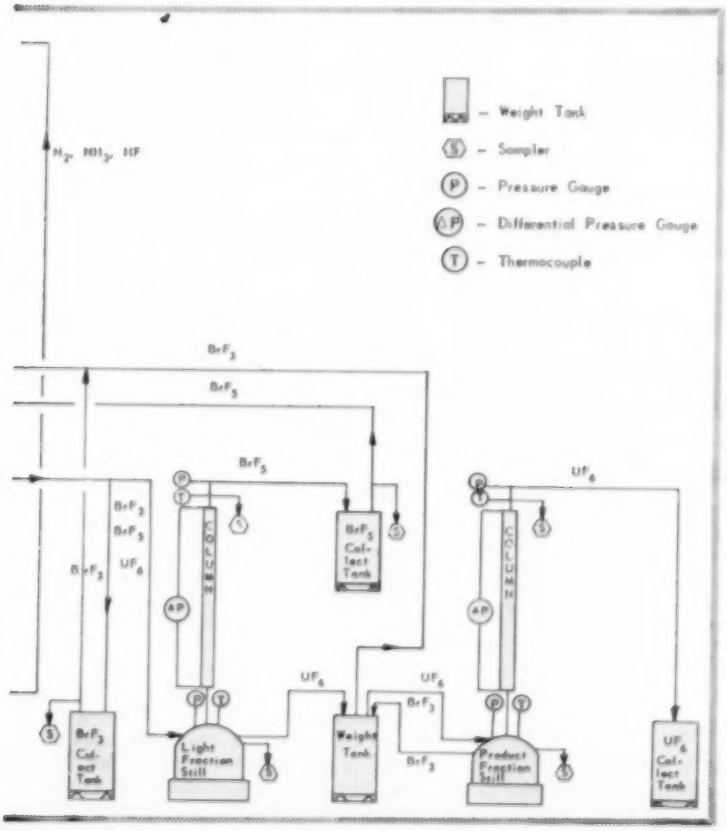
In run D-2, the initial dissolver solution contained 2.9 mole % UF_6. The reaction rate was sufficiently high so that above 60°C. no additional heat was supplied. In run D-3, six slugs were used with a dissolver solution containing 2.4 mole % UF_6.

Run D-4 was a 2-slug run similar to the above, but with a "hot spike" of four slices of irradiated uranium slugs. Run D-5 was a 2-slug run with irradiated uranium slugs. These were decanned in the dissolver with caustic. The aqueous-interhalogen changeover was accomplished without difficulty by purging and evacuating the heated dissolver.

Data on the overhead material collected during dissolution are given in Table 5. In run D-5 no material was taken overhead because the relatively small amount of uranium metal was not sufficient to change substantially the UF_6 composition of the dissolver solution. Differences in fractions of material taken overhead are attributed to the differences in UF_6 concentration in the dissolver.

* The "as received" purity of the BrF_5 used.

Fig. 1. Equipment schematic for fluoride volatilization process studies.



DECONTAMINATION

Table 1.—Process Steps

1. Dissolution of uranium metal in liquid bromine trifluoride
   a. $U + 2BrF_3 \rightarrow UF_6 + Br_2$ (dissolution)
   b. $Br_2 + BrF_3 \rightleftarrows 3BrF$ (equilibrium reaction)
   c. $Br_2 + 3F_2 \rightarrow 2BrF_3$ (regeneration)
   $BrF_3 + F_2 \rightarrow BrF_5$
2. Fractionation of mixture

Component	Temp. °C. corresponding to vapor pressure of 30 lb./sq.in. abs.
TeF_6	−25
BrF_5	+63
UF_6	+75
IF_5	+119
BrF_3	+150
NbF_5	+264
ZrF_4, PuF_4	nonvolatile

Table 5.—Overhead Collected During Constant Pressure Dissolutions

Run No.	Amount collected * (wt. % dissolver charge)	UF_6 content (wt. %)	Interhalogen composition
D-2	5.7	29.5	$BrF_{1.9}$
D-3	26.0	66.8	$BrF_{1.4}$
D-4	1.5	40.6	$BrF_{2.3}$
D-6	31.1	68.0	.....

* Collected in dissolver column overhead receiver.

Table 10.—Typical Corrosion in Nonsparged Fused Salts at 600° C.

Nickel and "L" nickel

Melt condition	Dimensional change, mils/day
HF saturated	0.1-0.6
BrF_3 saturated	0.5-3.0
Helium saturated	.02

Table 11.—Embrittlement Failures in HF Sparged Fused Salts

Material and component	Time to failure, hr.	HF rate, g./(hr.) (sq.cm.)
A Nickel liner	117	3.8
A Nickel liner	49	2.9
A Nickel liner	115	1.9
L Nickel (.050-in. wall)	629	3.2
L Nickel	408	5.2
Monel	1,188	4.6

All liners began with .032-in. wall unless indicated.

Table 6.—Uranium Decontamination Factors *—Run D-6

Operation	Decontamination Factors: Total beta	Total gamma	Te beta	I beta	Total fission product
Dissolver distillation					
UF_6 rough cut	1.6×10^5	1.3×10^4	14	2.1×10^5	1.6×10^3
Purification distillation					
UF_6 product cut	3.0×10^7	1.2×10^9	9.7×10^4	1.1×10^7	8×10^4
Overall	4.8×10^5	1.5×10^5	1.4×10^5	2.3×10^5	1.3×10^8

* Decontamination factor = $\frac{\text{activity/g. } UF_6 \text{ in charge}}{\text{activity/g. } UF_6 \text{ in product}}$

Table 7.—Summary of Decontamination Factors

	Run No. D-4	D-5	D-6
Cooling time of slugs (days)	348	197	80
Plutonium level of slugs (g./ton)	86	162	420
Activity level of dissolver solution			
1. Gamma (cts/min. MgU)	0.6×10^4	3.7×10^5	5.1×10^7
2. Beta (cts/min. MgU)	1.4×10^4	4.4×10^5	6.6×10^7
Activity level of product			
1. Gamma (% of natural U)	~0	~0	1.0
Gamma (d.f.)*	$>10^3$	$>2 \times 10^5$	1.5×10^6†
2. Beta (% of natural U)	~0.6	~2.5	2.0
Beta (d.f.)	3×10^4	$>2 \times 10^5$	4.8×10^5†
3. Plutonium (d.f.)	$>10^5$	$>5 \times 10^5$	$>10^6$
4. Total fission product (d.f.)	.....	.....	1.3×10^8
5. Tellurium beta (d.f.)	.....	.....	1.4×10^6
6. Iodine beta (d.f.)	.....	.....	2.3×10^6

* df = $\frac{\text{decontamination factor}}{\text{activity/g. uranium hexafluoride in charge}}{\text{activity/g. uranium hexafluoride in product}}$

† largely U^{237} activity

Table 8.—Decontamination Data from Laboratory Scale Run D-44

Melt	NaF-ZrF_4, equimolar, 300 g.
Equipment	2-in. diam. nickel dissolver
Temperature	600° C.
Pressure	1 atm.
Sample	irradiated Zr-U metal
Treatment	6 hr. HF sparge; 45 min. BrF_3 sparge

	Input	Decontamination factor on overhead fractions: HF condensate	BrF_3-UF_6 condensate
Nb	6.3×10^7 cts./min.-γ	96	123
Ru	0.16×10^7 cts./min.-γ	5,000	111
Zr	4.3×10^7 cts./min.-γ	250,000	5,000
Cs	0.64×10^7 cts./min.-β	5,000	9,100

Table 9.—Typical Corrosion in Sparged Fused Salts

Component	Gas	Temp. ° C.	Dimensional change, mils/day
Nickel and "L" nickel			
Liners	BrF_3	700	10-13
	BrF_3	600	3-8
	HF	600	.3-2
Hole radii	BrF_3	700	3.5-9
	BrF_3	600	1.5-7
	HF	600	0.4-1.5
Plate thickness	BrF_3	700	6-12
	BrF_3	600	1-1.5
	HF	600	1
Graphite (Type CS, ATZ, HC, HLM)			
Liner	HF	600	<.5
Hole radii	HF	600	<.5
Plate thickness	HF	600	<.1

At the end of each dissolution, any material taken overhead was returned to the dissolver and fluorinated by sparging with fluorine gas, with the end point indicated by disappearance of the red color of free bromine.

Table 6 gives the decontamination factors for the two main process steps in the high level run D-6. Table 7 summarizes the decontamination factors for the three active runs which have been made in the volatility pilot plant.

Results

In runs D-4 and D-5 the counting of the product was hampered because of the low activity levels involved. Run D-6 constitutes a stringent test of the process since because of the short cooling time considerable amounts of tellurium and iodine were present.

Gamma scans on the product from run D-6 immediately after collection showed no peaks except for U^{237} and a slight amount of tellurium. Another gamma scan (from 30 to 2,000 kev.) made after 140-days cooling showed no peaks other than those present in natural uranium.

There is no evidence of a nonvolatile tellurium compound; this is in agreement with the data obtained on laboratory scale experiments (6).

Substantially all the iodine entering with the slugs was contained in the recovered bromine trifluoride. A separate iodine-removal step is considered feasible but was not carried out in these operations.

The niobium and ruthenium activities in the recovered bromine trifluoride fraction were 8.8×10^3 and 3.4×10^4 gamma counts/(min.) (g. BrF_3) respectively.

The bromide contamination in the product has varied between 0.01 to about 2 wt. %. The product fraction from run D-6 contained 0.6 wt. % bromide. The required chemical purity is governed by whether the UF_6 product is to be used in the diffusion plant or in metal reduction.

Application of Process to Enriched Fuels

Distillation methods are not limited to the processing of natural uranium fuels. For example, zirconium-uranium fuels which do not dissolve in BrF_3, can be dissolved in a fused salt medium with a HF sparge at 600°C. The UF_4 produced during the dissolution then can be oxidized to UF_6 by a fluorinating agent such as BrF_5. The UF_6 can then be given further purification by distillation as described in the first part of this paper. A flowsheet which combines the fused fluor-

ide dissolution with purification of the product by distillation is given in Figure 4.

Table 8 shows decontamination data which have been obtained on a small scale for the fused salt dissolution and hydrofluorination steps. The data indicate that little NbF_5, RuF_5, or ZrF_4 fission products are carried into the overhead receivers. However, it was found that significant amounts of the niobium and ruthenium were volatilized from the dissolver and that they then condensed on the cold parts of the equipment connecting the dissolver to the overhead vessels. TeF_6 and IF_5 would also be volatilized; however, these fission products were not present in this run because of a long cooling time. Little entrainment occurs as indicated by the good decontamination factors for the nonvolatile cesium.

volatilization is conducive to corrosion of nickel equipment. The gas phase fluorinates the nickel, and the liquid phase dissolves the fluoride film. Fortunately, high rates of penetration of nickel appear to be economically allowable, perhaps up to several mils per day. Graphite is nearly immune to this environment and shows little dimensional change.

Another aspect of the corrosion problem is that of embrittlement. Materials having good resistance to embrittlement include Inconel and copper. Copper appears to be subject to mass transfer effects where thermal gradients exist, but otherwise appears to have necessary resistance. The chromium in Inconel depletes at a rate of 2-3 mils/day; though this may be acceptable the depleted layers spall off the parent metal and collect as a sludge in the bottom of the container.

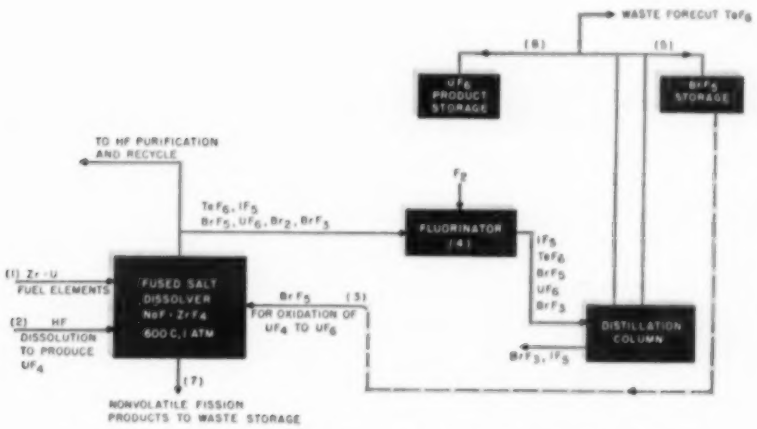


Fig. 4. Flowsheet for processing Zr-U fuels by volatility methods; fused salt process. Numbers in parentheses indicate order of operations.

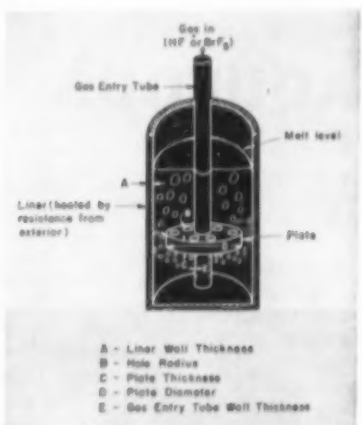


Fig. 5. Schematic of corrosion test apparatus.

Materials of Construction for Fused Salt Dissolver

The amount of corrosion to be expected in the fused salt process will be determined largely by the geometry of the equipment and conditions of operation. Materials of construction that appear to be the most promising are low carbon nickel, some high nickel alloy, and graphite. Both metal and graphite have limitations. Nickel corrodes at a high rate and is subject to embrittlement while graphites are porous in varying degrees. Penetration of graphite by salt combined with alternate heating and cooling could result in spalling and subsequent exposure of the back-up metal to the environment.

The alternate liquid phase—gas phase contacting that occurs during the fuel element dissolution and UF_6 volatilization is conducive to corrosion of nickel equipment. The gas phase fluorinates the nickel, and the liquid phase dissolves the fluoride film. Fortunately, high rates of penetration of nickel appear to be economically allowable, perhaps up to several mils per day. Graphite is nearly immune to this environment and shows little dimensional change.

Another aspect of the corrosion problem is that of embrittlement. Materials having good resistance to embrittlement include Inconel and copper. Copper appears to be subject to mass transfer effects where thermal gradients exist, but otherwise appears to have necessary resistance. The chromium in Inconel depletes at a rate of 2-3 mils/day; though this may be acceptable the depleted layers spall off the parent metal and collect as a sludge in the bottom of the container. Nickel-copper and nickel-molybdenum alloys have shown some promise in preliminary testing.

The corrosion test apparatus made to obtain data is shown in Figure 5, and typical results are shown in Tables 9 and 10.

Effect of Design

Corrosion of the container could be reduced by utilizing a frozen wall of salt. This could be done by introducing heat centrally and cooling the outer container wall. A cylinder of graphite or nickel might be used to isolate the gas and the container and thus reduce the attack.

Nickel Embrittlement

The embrittlement of nickel appears to be its most serious limitation. Its exact nature has not been determined, but it is likely related to the presence of sulfur in either the fused melts or the sparge gases. Low carbon nickel (.02% max.) appears more resistant than A nickel (carbon is .15% max.) as does Monel. Data regarding such failures are shown in Table 11.

Acknowledgments

A considerable number of the personnel of the Chemical Engineering Division contributed to the testing and operation of the equipment. The initial design and construction were done under the guidance of M. Levenson. The assistance of C. Crouthamel, R. P. Larsen, and L. Ross of the Analytical Section is gratefully acknowledged. The chief steps of the process now employed have been developed under the direction of R. C. Vogel. Valuable guidance and encouragement of pilot plant operations was given by W. A. Rodger.

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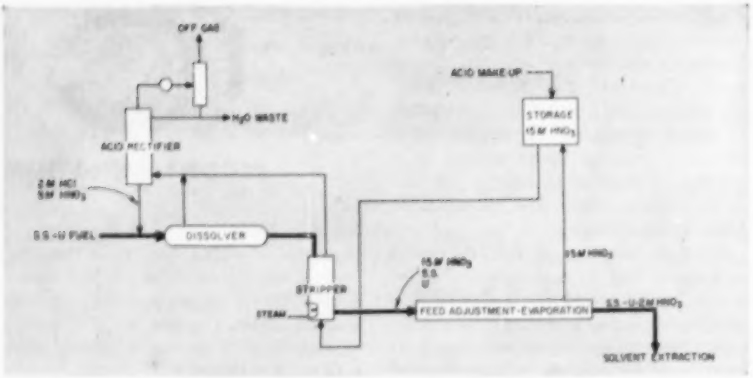

Fig. 1. Darex process.

preparation of power reactor fuels for AQUEOUS PROCESSING

The status of new methods for converting fuels fabricated of nitric acid insoluble metals to nitric acid solutions suitable for reprocessing by solvent extraction is presented. The Darex process uses dilute aqua regia to dissolve stainless steel fuels and distillation to recover HCl and HNO_3 in titanium equipment. The product feed solution is essentially free from chloride. The Zircex process uses HCl gas or a liquid inorganic chlorinating agent to remove selectively zirconium from jacket or core alloys at 300-400° C. as volatile $ZrCl_4$. The residues are nitric acid soluble. A final section summarizes data on aqueous dissolution techniques for jackets or core alloys.

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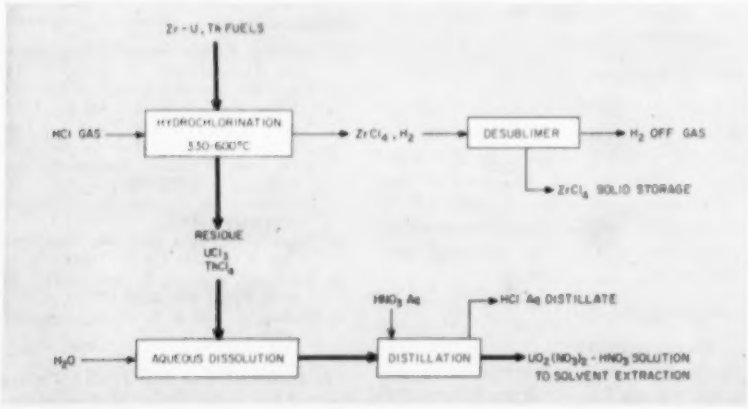

Fig. 4. Zircex process: gas-phase hydrochlorination.

Conventional reprocessing techniques utilize caustic and nitric acid dissolution as the head-end method for converting aluminum-jacketed thorium and uranium fuels to nitrate solutions suitable for solvent extraction. The proposed use of nitric acid insoluble metals such as stainless steel, zirconium, niobium, and silicon as construction materials has necessitated the development of new reprocessing methods and concepts. Under these concepts the head-end steps represent a major development area, and in all likelihood a major area of capital investment, compared to the relatively minor role simple nitric acid dissolution has played heretofore.

A number of homogeneous head-end reprocessing techniques, including hydrochlorination, aqua regia dissolution, oxidation, molten metal dissolution, and electrolytic dissolution have been surveyed and reported (*1*). These processes differ from other proposed (*2, 4*) approaches to power processing since they do not require the use of sulfuric acid or fluorides for dissolving stainless steel and zirconium, respectively. Use of mineral acids other than nitric in the solvent extraction system is not desirable since they are corrosive, decrease extraction efficiency, are not easily removed from process streams, and hence increase radioactive waste-storage costs. These disadvantages are relative, of course, and may not govern cases where small amounts of acids are required to remove thin jackets from fuels.

Two alternate concepts of head-end processing warrant consideration: (1) mechanical processing by chopping or dejacketing to expose cores to chemical dissolving media, and (2) homogeneous chemical processing. Homogeneous methods offer the advantages of high-throughput, versatile equipment, but have the disadvantage in many cases of carrying the inert fuel structural metals through the first cycle of solvent extraction, such methods thus decreasing throughput and increasing radioactive waste-storage volumes. Only homogeneous methods now being developed for application to a multipurpose solvent extraction plant will be presented in this article.

* Messrs. Savolainen and Blanco are associated with the Chemical Technology Division.

Darex Process

The Darex (*1*) process is the name applied to the use of dilute aqua regia as a head-end process for dissolving all types of stainless steel fuels and the elimination of chloride by distillation prior to solvent extraction. An idealized flowsheet now being tested is shown in Figure 1. The fuels are dissolved in about 5M HNO_3—2M HCl and the solution passed countercurrent to azeotropic (15.2 M) HNO_3 where the chloride is stripped from the liquid. The overhead gases are recovered in a rectifier and any noncondensable chloride vapors passed to a "cold" waste system via a caustic scrubber. Bottoms containing the metals pass to a feed preparation step where any remaining chloride is removed by decomposition during the feed boildown adjustment step.

The advantages of this method include rapid dissolution of all fuel configurations in a single head-end dissolver system, elimination of mechanical processing, hydrogen-free dissolver off-gas, and continuous high-throughput operation. Its principal disadvantages are corrosion and the carry-through of inert metals to the radioactive wastes storage system. Results to date indicate that titanium or tantalum will be satisfactory materials of construction for the head-end system.

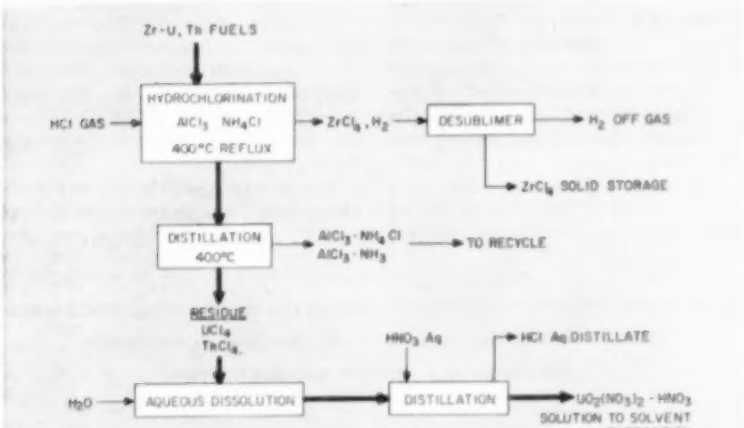

Fig. 5. Zircex process: liquid-phase hydrochlorination.

DISSOLUTION

The average dissolution rate of stainless steel is rapid and varies from 2.0 to 78 mg./(min.)(sq.cm.), depending on acid and metal concentrations (Figure 2). These rates are favorable when compared to 3 to 5 mg./(min.)(sq.cm.) which is normally considered satisfactory. As a result, dissolution is not the limiting processing rate for the Darex process, as is often the case, and dissolution conditions can be chosen to reduce corrosion, heat output, or achieve other desirable objectives.

Considerable decomposition of chloride to volatile chloride compounds takes place during the dissolution reaction, such decomposition amounting to 22% in the case of a 15-min. dissolution to 46 g./liter of 304 stainless steel with 5.0 M HNO_3-2.0 M HCl. This is significant in interpreting the curves shown in Figure 2 where the apparent rate of dissolution decreases with increased initial acidity. Actually, the rate decreases because the chloride has been rapidly removed from the solution as a volatile oxidation product because of the interaction of HNO_3 and HCl at high acidities. However, the nitric acid decomposition reaction is slow relative to the dissolution reaction at low acid concentrations. It is not known as yet what fraction of the gaseous chlorides can be recovered in the rectifier.

Hydrogen has not been detected in Darex dissolver off-gas. This will be a decided advantage when comparing alternate dissolution methods. This is of particular interest when one considers the direct dissolution of Na or NaK bonded fuels by Darex. Direct dissolution is expected to be feasible since the amount of NaK concerned is so small in comparison to the rate of metal dissolution. This method eliminates the necessity of mechanically dejacketing this fuel type. In an initial experiment a stainless steel prototype fuel containing a 4-mil sodium bond was successfully dissolved in the laboratory. The reaction behavior was not considered so violent as to preclude processing in this manner. Larger scale tests are planned.

DISTILLATION

Chloride must be removed from the dissolver solution to prevent corrosion in the solvent extraction and radioactive waste systems. Since distillation is proposed as the method of eliminating the chloride ion, a study of the vapor-liquid equilibrium for HNO_3, HCl, H_2O systems, both in the presence and absence of metal ions, was undertaken with the use of Gillespie stills.

Previously reported data (*3*) obtained by P. F. Hagerty and A. N. Hixson on the relative volatility of HCl and HNO_3 did not cover the concentration ranges completely. Data obtained at O.R.N.L. (*6*) for the pure system confirm the findings that significant separation occurs, particularly at higher hydrogen ion concentrations (Figure 3). Further studies also showed that the oxidation of chloride by nitric acid was slow when the total hydrogen ion concentration was less than 5 M. Calculations indicate that optimum conditions for separation in the stripping column are a vapor to liquid ratio of 1.5 : 1 and a stripping vapor composition of 20 mole % HNO_3. Under these conditions a feed containing 4.3 mole % HCl and 7.3 mole % HNO_3 should be stripped to an HCl content of 0.002 mole % (about 30 p.p.m.) in three theoretical stages. The presence of iron retards the distillation of the chlorides by the formation of a complex. The presence of the chromium and nickel does not exhibit any pronounced effect on the distillation.

The chloride content of stainless steel Darex solutions have been reduced to 20 p.p.m. in initial stripping experiments. In this case a solution containing 12.5, 3.2, 1.9, and 3.8 g./liter of Fe, Cr, Ni, and U, and 0.6 M Cl was passed countercurrent to 15.2 M HNO_3. Since approximately 10% of the chloride was oxidized under these conditions, lower concentrations of nitric acid are being studied now.

CORROSION

Initial 1,000-hr. corrosion tests indicate that titanium, Pfaudler glassed steel, and tantalum are satisfactory materials of construction for Darex. Corrosion rates for these materials in boiling 2M HCl—5M HNO_3 or 2M HCl—5M HNO_3 containing 100 g./liter of 304 stainless steel were 19, 6, and <0.6 mil/yr., respectively. Tentatively, titanium has been selected as the construction material.

Zircex Process

The Zircex process (*1*) is the name given to the application of hydrochlorination reactions for processing all types of zirconium-bearing fuels. Either a gas-phase or liquid-phase hydrochlorinating medium may be used. In the gas-phase reaction (Figure 4) the fuel is contacted with anhydrous HCl gas at 300-600° C. to volatilize $ZrCl_4$ from either jacket metal or core alloys. The uranium or thorium remains as a metallic or as a nonvolatile chloride residue. The chlorides can be dissolved in water, and the metal residue into nitric acid. In either case the chloride in the solution would be removed by Darex distillation, and the uranium or thorium recovered from the resulting nitrate solution by solvent extraction. In the liquid-phase reaction (Figure 5), a low melting fused coordination compound such as $AlCl_3 \cdot NH_4Cl$ plus HCl gas is used as a dissolution and hydrochlorinating agent. At 400° C. the melt refluxes and the volatile $ZrCl_4$ are removed as sublimation products. The melt is then distilled off and held for recycle. The residual uranium, thorium, and other nonvolatile metal chlorides are dissolved in water or nitric acid in preparation for solvent extraction.

The Zircex processes are in the early stages of development and their over-all potentialities are not known. They have the advantage of attacking all configurations of zirconium fuels and hence of eliminating or minimizing mechanical processing. They prevent the passage of the structural zirconium through the solvent extraction system and consequently optimize throughput and minimize radioactive storage volumes. The principal disadvantage in the gas-phase Zircex process is the difficulty in dissipation of the large heat of reaction. The gas-phase system seems to be particularly well suited to the natural or slightly enriched fuels where the zirconium content is low and jacket removal is the principal objective. Under these conditions the amount of heat to be dissipated is at a minimum.

GAS-PHASE HYDROCHLORINATION

The importance of heat control is shown in Table 1, which lists the effect of temperature on reaction rate and uranium losses during hydrochlorination of a prototype Zircaloy-2 clad U-Zr alloy fuel and various uranium core alloys. The reaction rates are generally satisfactory and increase with temperature and alloying metal content, ranging from 0.79-24.0 mg./(min.)(sq.cm.) when significant amounts of alloying metals are present. The rate was low, that is, 0.13 mg./(min.)(sq.cm.) at 400° C., for an alloy containing 99.25% U, 0.41% Zr, 0.12% Nb, and 0.22% Mo.

The uranium loss to the sublimate increases with temperature and is higher for alloys containing Mo or Al than for those containing Zr or Nb. The volatile uranium loss is excessive in the case of Zr-U or Nb-U alloys at temperatures higher than 450-500° C. These volatile losses are undoubtedly a function of equipment design and scale, however, and consequently should not be taken as exact parameters. The effect of alloying metals on the volatile uranium loss is not well understood.

The amount of uranium lost as a residue, which is insoluble in boiling 8M HNO_3, increased with temperature in the case of the Zircaloy-2 prototype fuel but showed no general pattern for the other alloys. This loss in the case of zirconium fuels appears to be a function of the amount of zirconium oxide present and subsequent formation of a solid solution with uranium. Both the cubic and monoclinic forms of ZrO_2 have been identified in the insoluble residue. If these uranium losses prove to be excessive, they could be recovered by treating the residue with carbon tetrachloride at 350° C. to form soluble chlorides, or dissolution in fluoride.

LIQUID-PHASE HYDROCHLORINATION

The liquid-phase Zircex process was devised to reduce or eliminate some of the engineering problems associated with the gas-phase process. The fuel element is dissolved in the first step of the process with the hydrochlorinating agent acting as a heat control and exchange medium.

Zirconium, Zircaloy-2, thorium, and uranium dissolve into molten ammonium aluminum chloride. Zircaloy-2 dissolves with a rate of 7.65 mg./(min.)(sq.cm.) at 330-370° C., and thorium dissolves at a rate of 4.9 mg./(min.)(sq.cm.).

When zirconium is reacted with ammonium aluminum chloride at 400° C. under refluxing conditions, the

Table 1.—Effect of Temperature on the Gas-Phase Zircex Process

(Laboratory-scale reaction with anhydrous HCl gas)

Alloy	Temperature (° C.)	Rate mg./(min.) (sq.cm.)	U Distribution, % of Total hydrochlorinator soluble *	insoluble *	sublimate
Zircaloy-2 clad U-Zr alloy (prototype fuel)	300	2.32	99.9	0.08	0.02
	330	3.13	96.3	1.35	0.05
	450	2.97	95.6	4.2	0.08
	600	4.20	55.5	7.73	36.8
	750	10.0	9.17	23.0	67.9
99.25% U-0.41% Zr-0.12% Nb-0.22% Mo	400	0.13	97.6	2.2	0.2
	500	.42	98.3	1.2	0.5
	600	2.22	93.2	0.3	6.5
90% U-10% Mo	400	2.96	99.9	....	0.1
	500	10.3	99.4	....	0.6
	600	24.0	88.3	0.1	11.6
93.4% U-5.3% Zr-1.3% Nb	400	7.65	99.9	<0.1	<0.01
	500	7.33	99.9	<0.1	<0.01
	600	2.78	99.8	<0.1	<0.1
97.9% U-2.1% Zr	400	1.25	99.9	0.08	<0.01
	500	2.83	99.7	0.26	<0.01
	600	9.55	99.3	0.65	0.09
98% U-2% Nb	400	0.77	98.7	1.26	0.01
	500	0.79	99.5	0.48	0.04
	600	0.75	97.7	1.04	1.24
15% U-85% Al	400	2.14	69.6	1.24	29.2
	500	1.04	83.6	1.11	16.2
	600	3.93	27.6	0.4	72.0

* Boiling 8 M HNO_3.

zirconium tetrachloride formed leaves the melt as a vapor. In this way about 95% of the zirconium has been separated from the uranium fuel during the dissolution step.

The uranium and thorium form chlorides which are nonvolatile and dissolve in the melt. Further studies have shown that the ammonium aluminum chloride can be distilled, leaving uranium and thorium chlorides as nonvolatile residues. About 0.2% of the uranium was volatilized with 67% of the melt.

CORROSION

The corrosion rates in mils per year were determined for the following metals in 500-hr. tests at 500° C. in anhydrous HCl gas: Inconel, 3.0; A nickel, 3.0; Hastelloy-B, 2.5; 304L stainless steel, 11.0. These metals therefore are satisfactory construction materials if the hydrochlorination and subsequent dissolution are performed in separate vessels. None of these materials is satisfactory if the same vessel is used for both operations, due to their high corrosion rates in chloride or chloride-nitrate solutions. Titanium and tantalum are unsatisfactory because of hydrogen embrittlement which occurs at 500-600° C. The removal of soluble chlorides with a water rinse may be a partial solution to this problem.

Initial tests of materials of construction for fused ammonium aluminum chloride show this fused salt to be quite corrosive. Type 304L stainless steel has a dissolution rate of 0.01 mg./(min.)(sq.cm.) in fused ammonium aluminum chloride at 380° C.; type 347 stainless steel, 0.017 mg./(min.)(sq.cm.); titanium, 0.8 mg./(min.)(sq.cm.); and tantalum, 0.61 mg./(min.)(sq.cm.) at 350° C. A systematic search has not yet been made to find a suitable material of construction.

Aqueous Dejacketing Methods

It has been reported (*5*) that concentrated boiling sulfuric acid may be a suitable dissolvent for zirconium cladding, and it is well known that hydrofluoric acid dissolves zirconium readily. Similarly, studies have shown that stainless steel can be dissolved in excess 6 M H_2SO_4 at an average rate of approximately 11 mg./(min.)(sq. cm.) at 100° C. However, no data were available on the reactivity of uranium or other core materials in these acids. This is important since the dejacketing solution could be discarded if it did not dissolve valuable materials and consequently would not complicate the extraction or waste systems. Initial studies have shown that both zirconium and Zircaloy-2 are soluble in a large stoichiometric excess of 14 M boiling H_2SO_4 at rates of 7 and 38-56 mg./(min.)(sq.cm.), respectively. Considerable amounts of H_2S, SO_2, and free sulfur are evolved. In experiments with prototype fuel a 28-mil Zircaloy-2 jacket was dissolved from a 0.36-in. diam. UO_2 core along with approximately 0.2% of the uranium. In another experiment a 4-mil zirconium jacket was removed from a 0.12-in. diam. 10% Mo-U core with a 100% stoichiometric excess of boiling 1 M HF. The solution was filtered and 0.42% of the uranium was found in the filtrate. Apparently oxidation of UF_4 to soluble UO_2F_2 occurred. Jacket removal experiments with boiling 6 M H_2SO_4 have not been performed but dissolution rates of 0.03 and 0.008 mg./(min.)(sq.cm.) were determined on uranium metal and 10% Mo-90% U alloy, respectively. Although the above evidence is preliminary and not conclusive, it is probable that dejacketing solutions cannot be discarded, particularly if plutonium losses prove to be of the same magnitude as the uranium losses. The final decisions will await the determination of both the amounts of uranium and plutonium lost in the aqueous dejacketing step.

Acknowledgment

Many people were engaged in this work carried out at Oak Ridge National Laboratory. The authors wish to acknowledge especially A. H. Kibbey, C. D. Watson, G. A. West, C. E. Guthrie, Oak Ridge National Laboratory; M. L. Hyman, The Pfaudler Company; H. F. Johnson, University of Tennessee; and R. C. Reid, D. T. Morgan, G. W. Bond, Jr., Massachusetts Institute of Technology Engineering Practice School.

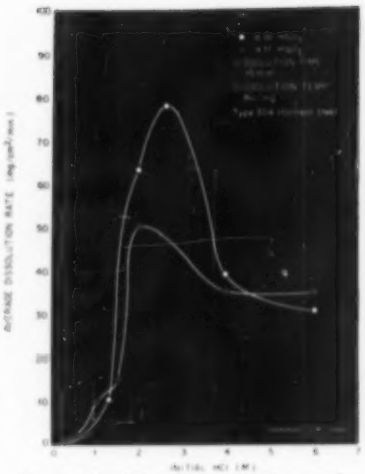

Fig. 2. Dissolution rate of stainless steel in HCl-HNO_3

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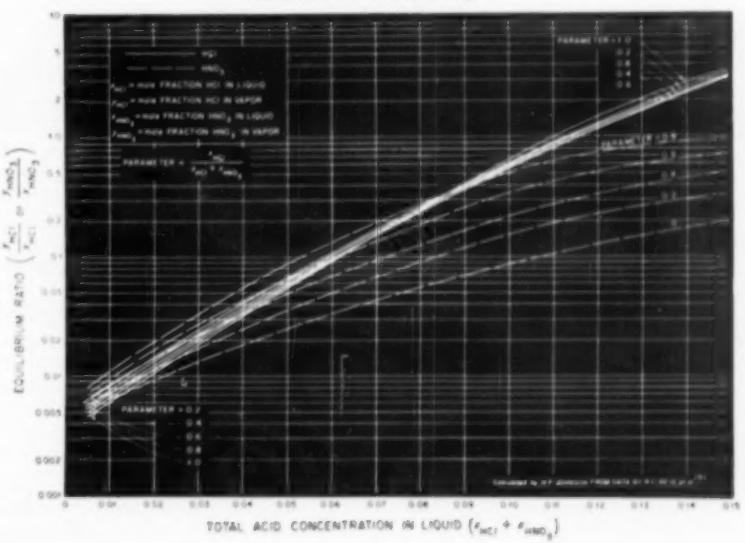
Fig. 3. Vapor-liquid equilibrium in HCl-HNO_3-H_2O system (based on experimental data from M.I.T. EPS-X-258).



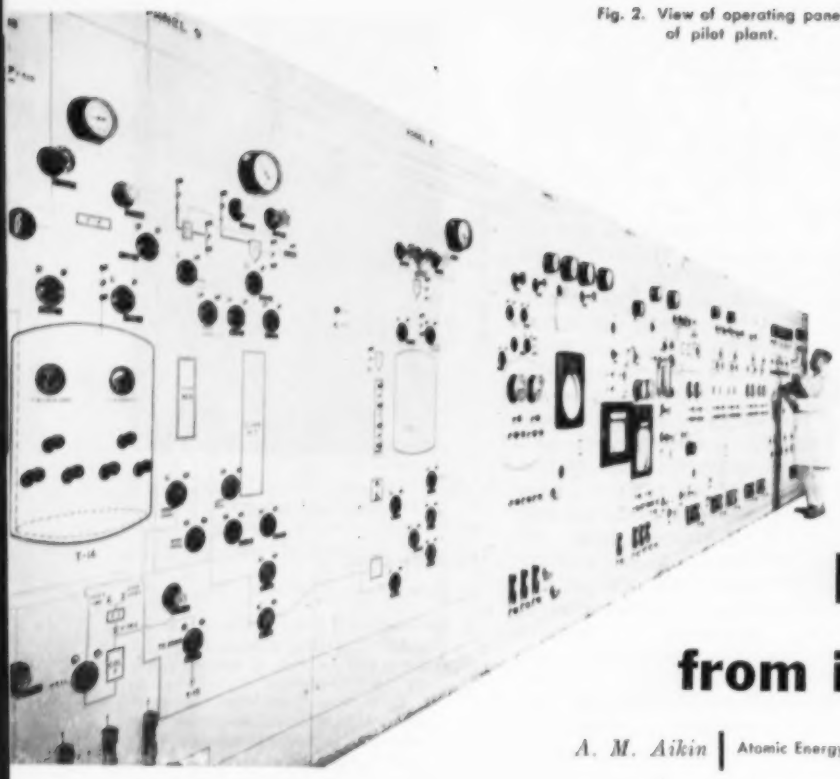


Fig. 2. View of operating panel of pilot plant.

ION EXCHANGE recovers PLUTONIUM from irradiated fuels

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There is considerable interest in the development of small specialized fuel reprocessing plants, particularly for countries where the quantities of fuel to be produced by the power reactors will not be sufficiently large for some time to come to justify large chemical processing facilities.

So, a small unit to reprocess irradiated uranium fuel for the removal by anion exchange of its plutonium content has been successfully operated at pilot scale.

Separation is achieved by absorbing Pu from an 8N HNO_3 solution on a strong base anion exchange resin, by washing the resin to remove uranium and fission products, then by eluting the plutonium with a low acid reducing solution. This cycle is repeated then to improve separation.

Historical Background

The original work on the application of ion exchange techniques to nuclear fuel processing was aimed at purifying and concentrating plutonium solutions obtained from solvent extraction systems. Cation exchange gave the highest concentrating factors but anion exchange gave excellent purification, both from many fission products and from iron and uranium. In fact the purification of plutonium was so good that the method was examined as a primary method of purification. Preliminary laboratory tests showed that plutonium could be recovered in high yield from a nitric acid solution of irradiated uranium by use of anion exchange resin. The decontamination factors for both fission product activity and uranium were at least 1,000. Thus the technique showed promise as a separation process.

At Chalk River a need arose for a simple plutonium recovery process. Uranium recovery could be included with this new process or could be done in the existing continuous, single cycle tributyl phosphate (T.B.P.) solvent extraction plant, which had proved unsuited to long-irradiated, short-cooled feed materials. Any new process also would have to recover plutonium from irradiated plutonium-aluminum alloy.

Two possibilities were recognized, the anion exchange process or a continuous T.B.P. process in a new plant. The choice between these two was not obvious because of the small size of the plants being considered and because of the existing units that could supplement any new process. Thus it was decided to investigate the anion exchange process and to compare it with the available information about the T.B.P. process. This article reports such development and comparison.

Process Description

A simplified flowsheet of the process is given in Figure 1. The nitric acid solution of the irradiated fuel is fed to the anion exchange column. The tetravalent plutonium is absorbed and most of the uranium and fission products pass on in the effluent. The column is washed with nitric acid solution to remove further uranium and fission products and then the plutonium is eluted with a dilute solution of hydroxylamine. The plutonium from this first cycle is not pure enough yet, hence it is put through a second cycle, the same as the first. Between cycles the plutonium solution is concentrated and the plutonium oxidized to the tetravalent state in an evaporator. The plutonium from the second cycle is concentrated in a second evaporator and then stored. The effluents are sent to storage tanks to await treatment and concentration.

Thus the process was simple in outline but, of course, there were many problems involved in each step. These will be discussed in turn, but first a description of the pilot plant is in order.

* Mr. Aikin is head of the Chemical Engineering Branch.

Plutonium can be separated from uranium by anion exchange, as demonstrated by a pilot plant operation described in this article. Advantage claimed is that a small ion exchange unit will recover uranium at $4.80/lb., which is cited as competitive with solvent extraction in larger unts.

Pilot Plant

The pilot plant was designed to have a capacity of 120 lb. U/day. Basically the plant was contained in a concrete block 18 ft. × 33 ft. × 12 ft., divided into individual cells, with each phase of the operation in a separate cell. Access to the cells was gained through removable stepped plugs in the top of the concrete block. The operating floor was on top of the plant. Figures 2 and 3 are two views of the operating area.

All lines and tanks were made of 347 stainless steel and, except in a few special cases, the lines were all welded. The valves, which were all located in a valve cell at the side of the block were air operated from the control panel. Lapp Pulsafeeder pumps were used, the pumping heads being in a shielded cell with the pumps on the operating floor.

Four primary anion colums were used, the feed passing through two in series. These columns, mounted in a special cell so that any one column could be removed readily, were 8 in. diam. by 36 in. long. A lead bottle was available into which the columns could be lifted thus providing the necessary shielding. A column could be changed in less than one hour. There was only one secondary column provided and it was smaller, being 4 in. × 36 in. It was removable in the same way as the primary columns.

The feed tanks were all weigh-tanks so that it was possible to check flow rates and also material balances. The evaporator at the end of the first cycle was capable of operation at reduced pressure. A deentrainment column of sintered stainless steel plates was tried but these were badly corroded and finally disintegrated. They were replaced with Pyrex raschig rings. The evaporators on the final product were of glass in order that no corrosion products would contaminate the product.

Plutonium Absorption

The main factors that affected the plutonium absorption were the plutonium, uranium, and nitric acid concentrations in the feed solution and also the flow rate. In Figure 4 is shown the effect of nitric acid on the resin capacity for plutonium. These values are the equilibrium values obtained by shaking plutonium solutions together with the resin until equilibrium is reached. The maximum capacity is obtained at 7.5 to 8N nitric acid. Column experiments confirmed this, even in the presence of up to 1M uranium.

The effect of uranium in solution was to decrease the capacity of the resin for plutonium. This effect seemed to be twofold; the equilibrium capacity decreased as did the rate of up-take of plutonium with increasing concentration. This gave a long "exchange band" and resulted in low operating capacities.

The pilot plant anion exchange columns were chosen to have a volume of 29 liters, with a feed flow rate of 0.75 ml./(min.)(sq.cm.) The operating capacities were expected to vary from one to more than 3 g. Pu/liter of resin, this variance depending on the plutonium concentrating in the feed solution. Five hundred liters of feed solution (200 g. U/liter) was passed through two such columns in series, then the first column was washed and eluted, and the second column became the first column for the next 500 liters of feed. When the plutonium concentration in feed was low, 750 liters was fed to three columns in series. In this way the column capacities were kept to a maximum.

The operating capacities obtained are shown in Figure 5 where the plutonium retained by the first anion exchange column is shown as a function of the plutonium concentration in the feed solution. It will be noted that for short irradiated uranium where the plutonium concentration is low, the equilibrium capacity of the resin also is low but it increases as the amount of plutonium in the solution increases. The operating capacities obtained were not as high as the equilibrium capacities obtained in the laboratory experiments. This might indicate that at the relatively high uranium concentrations the exchange band length was long and the first column in the series was not saturated.

Initially the feed flow rate was set at 0.75 ml./(min.)(sq.cm.). This was gradually increased to 1.5 ml./(min.)(sq.cm.) without any significant increase in plutonium lost in the effluent. The maximum flow rate commensurate with a low plutonium loss will probably depend on the uranium and plutonium concentrations but accurate data are not available.

The plutonium lost in the effluent varied from 0.5 to 1.2%. Indications are that most of this loss was due to hexavalent plutonium, which is not strongly absorbed at these nitric acid concentrations. No pretreatment of the feed was used but the addition of nitrite is recommended for future operations.

WASHING OF PRIMARY COLUMNS

After the absorption of the plutonium the columns were washed to remove most of the absorbed uranium and fission products. The effectiveness of this wash is shown in Figures 6 and 7. In Figure 6 the uranium concentration in the wash effluent is shown as a function of the wash volume for three different cases: a 4-in. glass column, with 10N HNO_3 wash, and the two 8-in. pilot plant columns with 8N and 10N HNO_3. There is a difference in results between the two sizes of columns. This might be due to channeling in the big column, but other results tend to disprove this theory. The higher acidity removed the uranium a little faster than the 8N nitric acid. A wash volume of 15-column volumes (450 liters) was

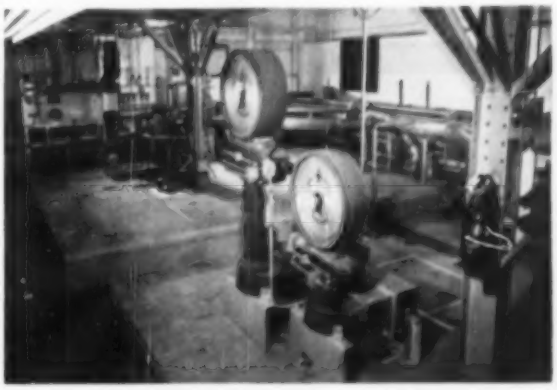

Fig. 3. View of top of concrete block, showing scales from which weigh tanks were suspended. Removable concrete blocks can also be seen.

Table 1.—Analysis of Typical Plutonium Product from First Anion Exchange Cycle

Plutonium	1.0 g./liter
Uranium	1.5 g./liter
β counts/(min.)	2×10^7 (~5% geometry)
DF_β	3×10^5

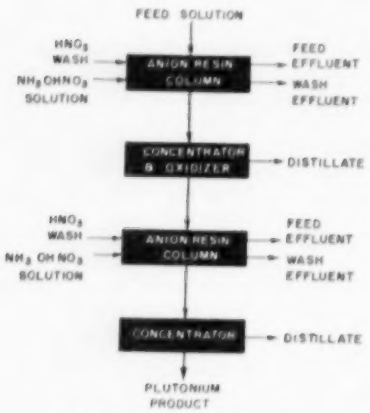

Fig. 1. Outline of process.

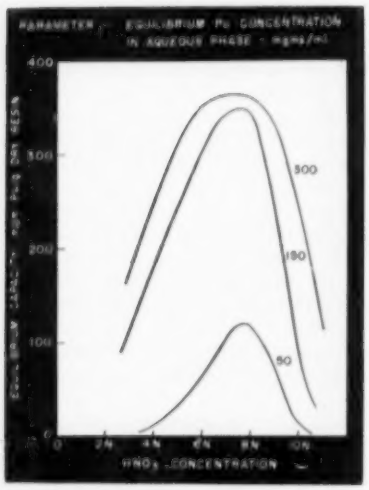

Fig. 4. Effect of HNO_3 concentration on plutonium absorption. Parameter: equilibrium Pu concentration in aqueous phase—mg./ml.

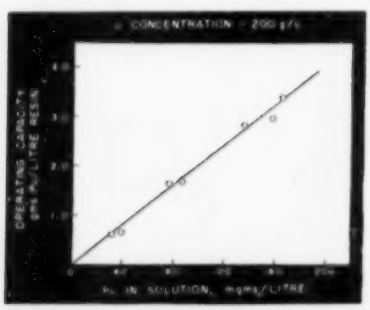

Fig. 5. Variation of operating capacity with Pu concentration. U concentration—200 g./l.

chosen to give adequate removal of the uranium.

The effectiveness of the wash for removal of fission products is shown in Figure 7 where the beta counts on the wash solution, as a measure of fission product concentration, is plotted against the wash volume. It appears from these results that the fission product activity in the wash levels off after about 15 column volumes (~450 liters).

The flow rate of the wash was varied from 1.5 to 3.3 ml./(min.)(sq.cm.) without much effect on the wash efficiency.

In routine operation the first half of the wash was sent to storage, but the second half was recycled as the first half of the next wash. This recycling saved considerably on waste volumes and did not reduce the efficiency of the wash.

ELUTION OF THE PLUTONIUM

It appeared that the most effective and consistent method of removing the plutonium from the resin was by reduction to trivalent plutonium in low acid conditions. Elution with 1N HNO_3 or lower concentration was possible, but results were only good with low cross-linked resin and varied from resin batch to resin batch. Thus a 0.5M hydroxylamine nitrate solution was chosen as the eluting agent. To prevent oxidation of this solution by contact with the high acid wash, a one-column volume spacer wash was passed through the columns before and after elution.

In the pilot plant the flow rate, the volume, and the concentration of the elutriant were all varied. Figure 8 shows a typical elution curve with the uranium and fission products in the elution or product stream. The flow rate was varied from 0.37 to 0.75 ml./(min.)(sq.cm.) and it can be seen that two-column volumes (60 liters) were needed to elute essentially all the plutonium at the highest flow rate tried. With lower flow rates less volume was required to elute all the plutonium, but it was considered impractical from the operating standpoint to try to use less than two-column volumes.

The concentration of hydroxylamine nitrate was reduced gradually from 0.5M to 0.1M without affecting the rate of elution. However, the 0.1M solutions were unstable and so a concentration of 0.15 to 0.2M was used.

The uranium that remained on the column after the wash was readily eluted with the plutonium. As shown in Figure 8, certain fission products, believed to be mainly niobium were also eluted, although a little more slowly than the plutonium.

During the elution when the hydroxylamine reacts with the plutonium, gas is evolved. No trouble occurred owing to gassing on the column. This gassing had been thoroughly studied in a 4-in.. glass column, and even operating under the most severe conditions no pressure build-up was observed. The pilot plant columns were equipped for vacuum degassing between cycles.

Secondary Cycle

An analysis of a typical plutonium solution from the first cycle is shown in Table 1. There was too much uranium- and fission-product activity associated with the plutonium to give a satisfactory product and so another anion exchange cycle was used to give further purification.

Conditions for the second cycle were generally the same as for the first except that, because of the low concentration of uranium now present in the solutions, the capacity of the resin for plutonium was much greater. The plant was not of "eversafe" design, thus a criticality limitation of 150 g.Pu/batch was used. In Table 2 is given the analysis of a typical plutonium product after it had passed through the two cycles. The decontamination factors are also given.

For certain feed solutions the final product contained too much fission product Zr-Nb. A silica gel column was installed and an additional separation factor from these fission products of 10 to 20 was obtained.

Intercycle Treatment

The plutonium from the first cycle was in the trivalent state in the hydroxylamine nitrate solution and it was necessary to oxidize it to the tetravalent state and to increase the acidity of the solution to 7.5 to 8N before feeding to the second cycle. Originally this was accomplished in the pilot plant by feeding the solution to an evaporator that contained boiling 7.5N nitric acid. The plutonium was oxidized and the hydroxylamine destroyed immediately it contacted the hot acid. Unfortunately, a poor grade of stainless steel was used in part of the evaporator pot and this was corroded by the hot acid, giving rise to chromium ion in the solution. This chromium ion catalysed the oxidation of the plutonium by the nitric acid to the hexavalent state. Hexavalent plutonium is not as readily complexed by nitric acid as is tetravalent material, and this resulted in poor absorption on the anion resin in the second cycle. As much as 20 per cent of the plutonium was not absorbed and had to be recycled.

To avoid this oxidation to Pu^{VI}, a

new system was tried. The plutonium-hydroxylamine solution from the first cycle was passed through a cation resin column (Dowex 50) and the plutonium was absorbed as Pu^{III}. This plutonium was then eluted with 7.5N nitric acid solution and fed directly to the secondary anion column. Good absorption was obtained, the plutonium losses being less than 0.1%. Gassing occurred from the oxidation of the plutonium on the cation resin column but this again was not a problem.

Processing of Pu-Al Alloy

The anion exchange process pilot plant was used to recover plutonium from some experimental slugs of plutonium-aluminum alloy. These slugs had been irradiated to approximately 50% burn-up and cooled for five months. They were dissolved in nitric-acid with mercury as a catalyst and then were fed to the anion exchange columns. The plutonium was absorbed and the aluminum-fission product solution passed through the column and was sent to waste storage. After it was washed, the plutonium was eluted with hydroxylamine solution. A decontamination factor from fission product activity of about 400 was obtained. The plutonium product was then recycled through the anion exchange cycle three times with fission product decontamination factors of 12, 2 and 2 to give an over-all DF_γ of about 2×10^4. Some plutonium was lost due to the formation of hexavalent plutonium during intercycle oxidation with the use of boiling 7.5N nitric acid.

RESIN STABILITY

One of the questions that had to be answered early in the development of the process was whether the resin would be sufficiently stable to chemical and radiation attack to have a useful and economically long life. Tests made in the laboratory indicated that chemical attack, even with 10M nitric acid, would be no problem and this has been borne out in the pilot plant, where resin that has been in contact with process solutions for over a year still performs satisfactorily. The published data of Higgins (*1*) was used to calculate the effect of radiation damage on the resin. With the use of these figures an estimate of the cost of replacing the resin, after its capacity was reduced by 25%, was made; this indicated that it would amount to \$0.07/lb. U processed or \$0.33/g. Pu when processing irradiated Pu-Al alloy. Unfortunately the pilot plant was not operated long enough to confirm these estimates but indications are that the resin damage is no higher than predicted.

Table 2.—Analysis of Typical Plutonium Product from Two Cycles of Anion Exchange

Uranium	1.5% of Pu
β activity	2×10^5 counts/(min.)(mg. Pu) = 2 mc./g. Pu
Zr-Nb^{95}	1.5 mc./g. Pu
Fe	0.3% of Pu
DF_U	2×10^5
DF_β	5×10^4

Economics of Process

Estimates have been made of the capital and operating cost of an anion exchange process plant that could handle 100 tons U/yr. The capital cost is estimated at \$815,000 and the total processing cost with 20%/yr. amortization, at \$3.10/lb. U or \$4.26%/g. Pu for 2,000 Mw. day/ton material. These costs do not include desheathing, dissolving, or waste disposing. The wastes, of course, contain uranium and so only a small amount of concentration is possible. If storage costs \$2.00/gal., this would be equivalent to \$1.70/lb. U, to give a total cost of \$4.80/lb. U after dissolving.

For such a small plant this cost is competitive with solvent extraction.

However, there is one major obstacle yet to be overcome: namely, the ion exchange process does not give sufficient separation from fission product activity to effect a plutonium that can be handled conveniently. The gamma irradiation associated with the plutonium product is too high.

Thus, further purification of the plutonium or remote plutonium fuel fabrication facilities, both of which would add to the cost, would have to be tied in with the process. The process might be useful for certain special and specific applications but certainly not as a versatile large-scale plant.

Acknowledgment

The anion exchange process for the recovery of plutonium was developed by a group of chemists and engineers at Atomic Energy of Canada Limited. To the author of this report has fallen the task of summarizing this work but he was only one of many associated with the development of the process. In particular the contributions of the following are acknowledged: G. M. Allison, R. G. Hart, A. J. Mooradian, I. A. W. Morrison, R. W. Durham, D. T. Nishimura, G. L. Brooks, and I. J. O. Korchinski.

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1. Higgins, I. R., "Radiation Damage to Ion Exchange Materials," O.R.N.L.—1325.

To be presented at 1957 Nuclear Engineering and Science Congress, Philadelphia, Pennsylvania.

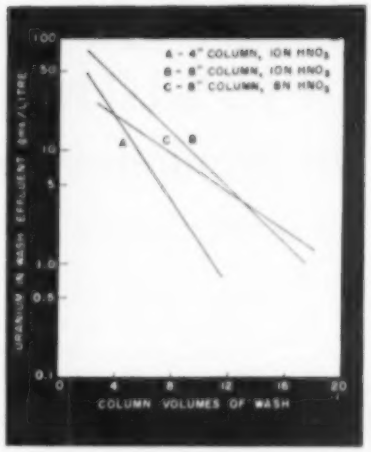

Fig. 6. Removal of uranium from primary column by wash.

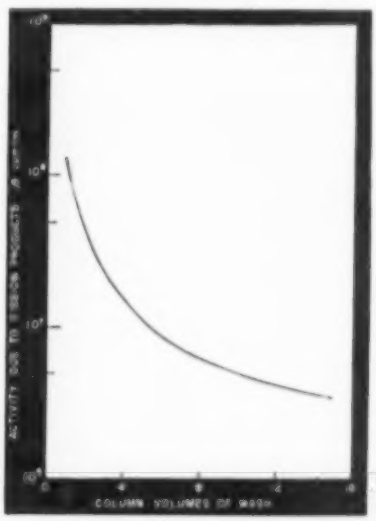

Fig. 7. Removal of fission products from primary columns by wash (8N HNO_3).

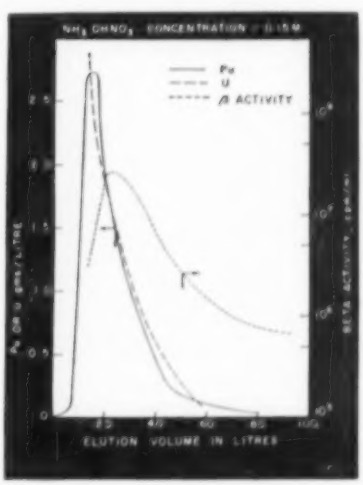

Fig. 8. Elution of primary columns. Flow rate: 0.70 ml./(min.)(sq.cm.) NH_2OHNO_3 concentration: 0.15M.

pilot plant generation of FISSION PRODUCTS in uranium-bismuth reactor fuel

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Molten bismuth, containing 800 p.p.m. of natural uranium and small amounts of corrosion inhibitors, was circulated at pilot scale through the Brookhaven reactor for generation of fission products therein. The recirculating metal stream was equilibrated with fused-salt mixtures and with helium gas to determine distribution coefficients for certain fission products between metal and salt and between metal and gas phases. Experimental results corroborated those previously obtained on small-scale tracer experiments and were favorable from an engineering standpoint.

One of the attractive features of the liquid-metal fuel reactor (L.M.F.R.) under development at the Brookhaven National Laboratory is the possibility of continuous fuel processing for removal of fission products. The fuel for this reactor system is a dilute solution of uranium in bismuth.

In the L.M.F.R. the fission products can be conveniently divided into three groups:

1. those which are volatile at the operating temperature of the reactor (F.P.V.'s);
2. those which form chlorides more stable than UCl_3 (F.P.S.'s); and
3. the remainder (F.P.N.'s).

The first two groups contain by far the worst reactor "poisons" and for this reason have received the most attention, as far as removal is concerned.

It is proposed to remove the F.P.V.'s by a simple volatilization, or degassing, process. The F.P.S.'s, on the other hand, would be removed by oxidizing to chlorides and extracting with a fused-salt mixture.

The use of fused chlorides for extracting fission products from a U-Bi solution was first proposed by Winsche and studied experimentally by Bareis at B.N.L. (*1, 2, 3*). Wiswall showed, by theoretical means, that these results were consistent (*2, 3, 15*). As a result of processing with LiCl-KCl salt, lithium moves into the bismuth stream where it can act as a reactor poison. Consequently, a different fused-salt eutectic—$MgCl_2$-NaCl-KCl (58, 24, and 18% by weight, respectively), has been suggested. Experiments were carried out with both salt systems.

The purpose of the work described in this paper was several fold as follows:

First, to obtain metal-gas equilibrium partition coefficients for xenon, the most important volatile fission product from the poisoning standpoint;

Second, to obtain metal-salt equilibrium partition coefficients for typical nonvolatile fission products; and

Third, to obtain operating experience with, and to test components of, a complex, all steel, radioactive facility in which molten U-Bi and fused salts were circulated in a pilot-scale "loop" at the commercially practical temperature of 500° C.

This loop, which will be described in detail, represented the first attempt at handling a U-Bi fuel containing live fission products under conditions approaching those which would exist in a commercial plant. In general, the objective was to compare equilibrium partition coefficients obtained under such conditions with those obtained previously in small-scale tracer-type experiments. The operational performance of the loop was evaluated in such practical terms as corrosion resistance of container material, reliability of measuring instruments, stability of fuel composition, performance of components, suitability of sampling methods, and problems of repair and maintenance.

Bismuth, containing 800 p.p.m. of natural uranium, was circulated through the loop, the U^{235} content of the mixture being limited by the gamma radiation levels produced in those parts of the loop which were external to the reactor. This U^{235} concentration gave, at steady state, fission-product concentrations as high as 10^{-6} p.p.m. and radiation levels as high as 0.4 mc./cc. These fission-product concentrations were lower than would probably be encountered in a commercial plant, but were still sufficiently high to give valuable and dependable experimental data.

Description

GENERAL

The principal features of the loop are shown in the flow diagram (Figure 1). In operation, the bismuth flowed through the in-pile section, where fission products were generated, to the degasser vessel for removal of the volatile fission products and then was pumped to the in-flow trap, contactor, and surge tank from which it was finally returned to the in-pile section.

The salt contacted the circulating bismuth in the upper half of the contactor for the duration of an experiment. Thereafter, it was transferred to the sampling vessel and drained to waste tanks.

Parts in contact with bismuth and fused salt were of Type 347 stainless steel. Operation was isothermal at 500° C. Flow rate was approximately 0.25 gal./min. Loop temperature was maintained at 500° C. throughout by resistance heaters.

The loop gas system consisted of a purified helium supply, a high vacuum system, and a low vacuum system. These were used to maintain a helium blanket over the bismuth and salt parts of the loop, to control the removal of volatile fission products from the degasser, and to control the operation of the fluid system in regard to liquid levels.

Operation

TRIAL RUN OPERATION (out-of-pile)

Prior to the insertion of the loop in the Brookhaven reactor, a trial run was made in which all parts of the loop were tested. During this run, the following procedures were used:

First of all, the loop was brought to 550° C. under vacuum to outgas the container walls. The rate of temperature rise was controlled to keep the pressure below 100 μ. When outgassing had ceased, the temperature was reduced to 500° C. Following this, bismuth containing 25 p.p.m. magnesium and 250 p.p.m. zirconium was charged to the sump tank from a portable melt tank. Within the first hour, the pumps and flowmeters were operating consistently and a flow of 0.8 gal./min. was established. Numerous tests were made to calibrate the flow meters and study the relationships existing between pump power, flow rate, and liquid level.

During the trial run, the loop was operated under vacuum to test the control equipment and stability of flow under conditions to be encountered in the degassing studies.

Fused LiCl-KCl eutectic salt, which had been pretreated with bismuth containing 1,000 p.p.m. magnesium and 1,000 p.p.m. uranium to remove hydrates and hydroxides, was added to the salt fill tank. A number of contacting runs was subsequently made to test the operating characteristics of the salt system.

The performance of the loop during the simulated experimental runs was, on the whole, entirely satisfactory. The difficulties which did arise involved component failures rather than basic process design faults. A leak developed in the in-pile supply pump cell which, while not large enough to permit bismuth to leak out, did permit air to enter the loop during operations conducted under vac-

uum. This cell was replaced and changes in the pump mounting were made. The liquid level equipment required some modification to provide a more rugged probe for measuring bismuth levels. Difficulty with one type of salt-level indicator necessitated the use of alternative methods for determining the contactor salt level. Some plugging of the salt drain lines was observed during the contacting runs.

The total operating time for the trial run was 1,648 hours.

In-Pile Operation

PROCEDURE

The in-pile section of the loop (Figure 2) was inserted into an experimental hole of the Brookhaven reactor, and bismuth circulation was started on June 5, 1955. A flow rate of 0.25 gal./min. was established. At the conclusion of brief performance tests and sampling, the reactor was brought to power and the build-up of activity in the loop began. A ten-day operation was allowed to permit the build-up of the volatile fission products after which the experimental program, consisting of metal-gas equilibrium studies, metal-salt equilibrium studies, and other related experiments was started.

Volatile fission-product distributions between bismuth and helium were obtained by maintaining a fixed volume of helium in contact with the flowing bismuth stream until equilibrium had been reached. Both phases were then sampled and analyzed for xenon and iodine.

The distribution of the significant nonvolatile fission products between bismuth and the fused salts was determined by first contacting the flowing bismuth stream with the salt for a sufficient length of time, then separating the phases, and sampling each one.

Other experiments of lesser importance involved variations in sampling techniques and are discussed in a later section.

Experimental work was carried out for approximately 4,700 hr. without incident until leakage difficulty with one of the electromagnetic pumps was observed. Operation was continued, however, with a careful check to detect any spread of alpha contamination, until the failure of the sump tank heaters forced the dumping of the loop. The total in-pile operating time was 6,446 hours. The loop and related equipment are shown in Figure 3.

PERFORMANCE

Loop and Components

The loop functioned satisfactorily during the major part of the experimental program. No difficulty was

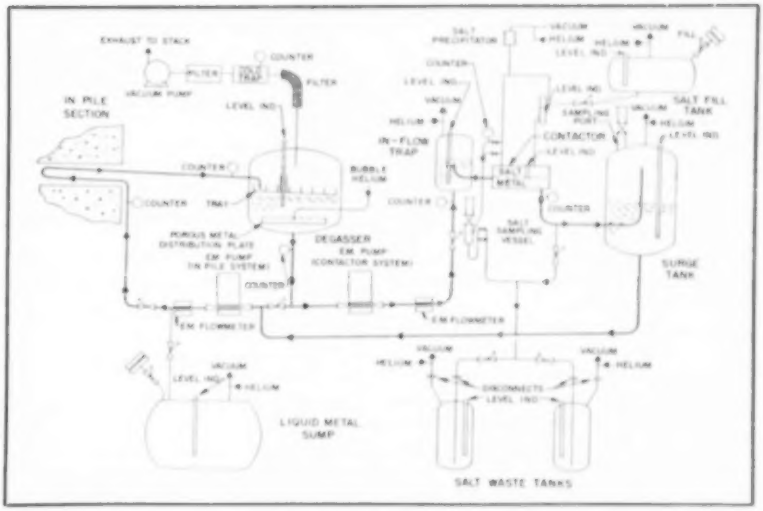


Fig. 1. Flow diagram.

Fig. 3. Loop in operation at reactor.

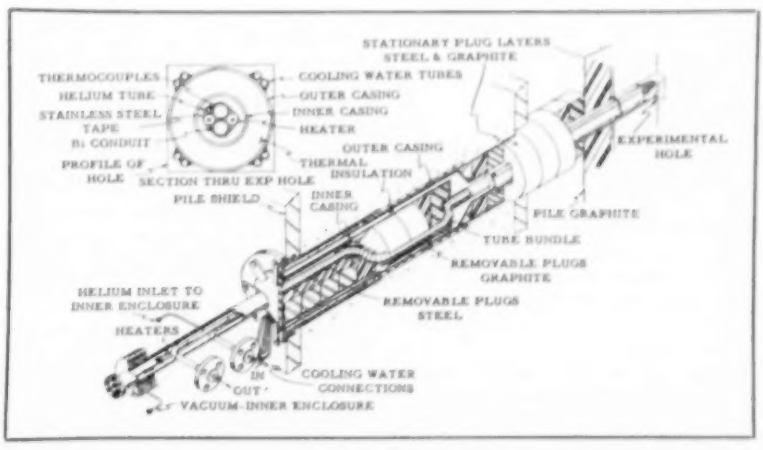


Fig. 2. In-pile section.

experienced during the work with the volatile fission products until after a leak developed in the electromagnetic pump. Whereas this prevented experimental work at reduced pressures, it did not prevent distribution determinations at positive pressures.

At the end of the metal-LiCl-KCl salt-contacting runs, partial plugging of the salt lines was observed. This plugging cleared up rapidly when experiments with the $MgCl_2$-NaCl-KCl eutectic were started.

An indication of the initial cleanliness of the loop and its capability of being operated over long periods of time without contamination by oxygen is shown by the stable concentrations of the fuel stream additives (Figure 4). The concentration of uranium remained at 800 (±7%) p.p.m. for better than 5,000 hr.

This concentration could have been maintained indefinitely if the J-1 pump cell had not cracked, a condition which allowed oxygen to leak into the loop. At that time, the uranium concentration decreased to 740 p.p.m., where it remained until loop shutdown. Both the magnesium and zirconium concentrations also decreased after this event. The concentration of magnesium was maintained at constant values of 15 p.p.m. and 22 p.p.m. (±20%) respectively until the salt-contacting experiments were started. This is discussed in a later section. The zirconium concentration remained stable at 205 p.p.m. (±5%) except during the binary salt-contacting runs.

The enclosure and exhaust system very satisfactorily contained the alpha contamination that escaped from the leak in the in-pile supply pump. Up to 3,000 counts per minute were observed in the main enclosure at the point of leakage. Levels were down by a factor of nearly 1,000 within a foot of this point. No buildup in activity was observed outside the enclosures.

Sampling and Analysis

Sampling, the improvement of sampling techniques, and the analysis of the samples constituted the major expenditure of effort during the operation of the loop.

SUBSTANCES DETERMINED

Equilibrium distributions between bismuth and helium were determined for I^{133}, Xe^{133}, Xe^{135}; between bismuth and salt for Cs^{137}, Ba^{140}, Ce^{143}, total rare earth fraction, Zr^{95}, and Ru^{103}. These were then compared with data obtained in earlier experiments.

The concentrations of Po^{210} (the product of neutron capture by bismuth), loop additives (U, Zr, Mg), and corrosion products (Cr, Mn, Fe, Ni) were determined as a function of time.

BISMUTH AND SALT SAMPLING

The bismuth stream and the salt were both sampled with the thief-type sampling method (*11*).

The bismuth stream sampler was mounted on the surge tank. The salt sampler was mounted on a special sampling vessel into which the salt was introduced following each contacting run.

Samples were obtained by first inserting a sample tube into the upper air lock through a Teflon sliding seal and purging the air lock to remove the air and introduce helium. Following this, the ball valve was opened and the sample tube lowered into the liquid. While the tube was being lowered, helium was blown through it to prevent the taking of a sample until desired. At the time of sampling, the helium flow was stopped and the pressure between the tube and the vessel was equalized, allowing a bismuth or salt sample to enter the tube. The sample tube was then withdrawn, and the ball valve closed.

Great care was taken in the preparation of the metal sampling tubes. These were carefully cleaned mechanically and degreased with acetone. The tubes were then outgassed at 950° C. until a vacuum of less than 1 μ was obtained. In this manner, only steel, whose surface was at least as clean as the loops, was introduced to collect samples and foreign matter was kept at an absolute minimum. A modification of the standard sampling tube was used to obtain corrosion product samples. In this case, a graphite sleeve was placed in the sample tube and arranged so that the sample could not come in contact with the steel wall of the tube.

GAS SAMPLES

The gas stream from the degasser was sampled by diverting the flow of gas through a glass canister in which the samples could be trapped. In nonflow operation, where the volatile fission products were being allowed to build up for equilibrium distribution studies, the gas phase was sampled by evacuating the sample canister and then collecting the sample.

DETERMINATION OF SOLUBILITY OF XENON—EXPERIMENTAL PROCEDURE

Considerable difficulty was experienced in devising a method to determine the extremely low solubility of xenon in bismuth.

The following method finally gave consistent results. The loop was sampled for bismuth in the usual manner through the surge tank, but with clean, degassed carbon steel tubes. The tubes were frozen in liquid nitrogen between the time of sampling and analysis. The entire tube and contents were dissolved then in nitric acid in the dissolver of the analytical system, and the xenon removed and analyzed. The elapsed time between sampling and the initial steps in the analysis was critical; the shorter this interval, the more sensitive the data.

All xenon present in the sample was removed and measured immediately. All the additional xenon formed from iodine decay in the same sample, after a given time interval (usually 1 hr.), was removed again and measured. Its value was added to the first result. Several additional cuts were similarly obtained and the build-up curves of Xe^{133} and Xe^{135} were constructed and compared with theoretical build-up curves. If xenon was present at the time of sampling (that is, if its solubility in bismuth was measurable), then the two curves would differ from the theoretical curves. An optimum curve was then constructed through experimental points and the xenon present in the bismuth at the time of sampling (that is, its solubility) was determined by means of trial-and-error calculations (Figure 5).

DETERMINATION OF FISSION PRODUCT DEPOSITION ON SOLID SURFACES

The concentration of fission products and other elements depositing on the solid surfaces was determined. Samples of several different materials (Type 347 stainless steel, 2¼% Cr-1% Mo steel, various types of graphite, and ZrN-ZrC) were introduced into the loop for varying lengths of time, and the resultant fission-product activity measured. The samples were carefully cleaned and outgassed under vacuum at 950° C. prior to use, so that their surface was in a condition comparable to that in the loop.

The steel samples consisted of four disks, each ½-in. diam. and 3/64 in. thick, suspended on a steel rod running through a hole in the center. The total area was 1 sq.in. Steel tubes, ¼-in. diam. with an area of 0.75 sq.in., also were used. The graphite samples were approximately 1 1/32-in. diam. and 1½ in. long.

Experimental Results

METAL-GAS EQUILIBRIA

Equilibrium concentrations of Xe^{133} and Xe^{135} in bismuth and in the helium gas phase at 500° C. and a static gas pressure of 4 lb./sq.in. gauge are shown in Table 1. There is considerably more scatter in the data for Xe^{135} than for Xe^{133}. This may be due to the fact that at equilibrium there is sixteen times more of the latter present. Furthermore, the Xe^{135} is determined by difference from the composite $Xe^{133-135}$ decay curve.

Average concentrations of Xe^{133} and Xe^{135} in the bismuth were 6.6×10^7 and 1.6×10^6 atoms/cc. bismuth, respectively, and in the gas, 1.1×10^{10} and 1.3×10^9 atoms/cc. helium, respectively. If it is assumed that the solubility of xenon in bismuth follows Henry's law, then $p = kx$

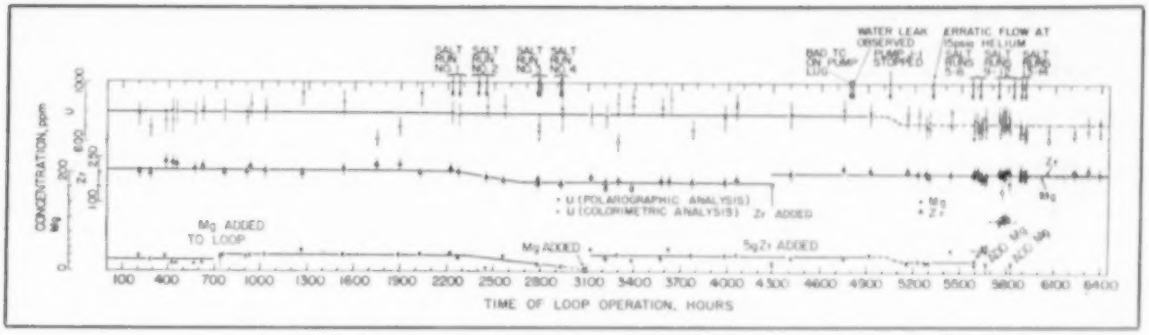


Fig. 4. Variation of the concentration of bismuth additives with time.

and at 4 lb./sq.in. gauge helium and 500° C.,

$p_{Xe^{135}} = 1.2 \times 10^{-9}$ atm.
$p_{Xe^{133}} = 1.4 \times 10^{-10}$ "

and

$x_{Xe^{135}} = 2.3 \times 10^{-15}$ mole fraction
$x_{Xe^{133}} = 5.7 \times 10^{-17}$ " "

therefore,

$k_{Xe^{135}} = 5 \times 10^{5}$ atm./mole fraction
$k_{Xe^{133}} = 2 \times 10^{6}$ " "

or

$k_{avg.} = 1.3 \times 10^{6}$ " "

The xenon solubility in bismuth at 500° C. and 1 atm. (xenon) is, therefore, 7.7×10^{-7} atoms xenon/atom bismuth (~0.4 p.p.m.).

Comparatively little information is available on the solubility of xenon in bismuth. McMillan (9) has calculated its solubility in bismuth on the basis of theory, and Mitra and Bonilla (10) have determined the solubility of xenon in bismuth experimentally with capsule samples using tracer techniques. The work at B.N.L., then, represents the first data on the solubility of xenon in bismuth and its metal-gas equilibrium distribution in a dynamic system. The B.N.L. solubility data compare favorably with the results obtained by Mitra and Bonilla, and the extrapolated values of McMillan. (See Table 2.)

METAL-SALT EQUILIBRIA

Variation of Additives with Time

Four binary-salt-contacting runs were made with contact times of 43.5 and 47 hr., and 4.5 and 4 hr., respectively. The wide time variation was chosen to determine its effect as a variable. The fuel stream was contacted with the ternary salt for the shortest time feasible in loop operation —about 3 hr. The magnesium concentration was varied to note its effect on the partition coefficients and to compare it with the laboratory data. Four runs were made at a magnesium concentration of 30 p.p.m., four at a concentration of 75 p.p.m., and two at a concentration of 135 p.p.m.

The effects of contacting on the concentrations of uranium, magnesium, and zirconium are shown in Table 3 and Figure 4. The uranium concentration in the metal remained unchanged at 800 p.p.m., while its concentration in the salt remained at low values for all four binary-salt-contacting runs for an average partition coefficient * of 0.048. The magnesium concentration in the bismuth decreased from 22 p.p.m. to 9 p.p.m., with a corresponding, almost quantitative, increase in the salt. The zirconium concentration in the metal also decreased for the first two runs from 205 p.p.m. to 175 p.p.m. and then remained at a constant value for the last two runs. Its concentration in the salt was not enough to account for the loss.

The uranium concentration in the metal remained constant at 740 p.p.m., while its concentration in the salt was low for all ten ternary-salt-contacting runs. After the initial runs with the $MgCl_2$-NaCl-KCl eutectic, and for an unexplained reason, the magnesium concentration in the bismuth increased from 15 p.p.m. to 30 p.p.m. Two successive additions of magnesium then raised its concentration to 75 p.p.m. and 135 p.p.m., respectively, for subsequent salt-contacting runs. Of course, no magnesium analyses were made on the ternary-salt mixture, owing to its high $MgCl_2$ content. The concentration of zirconium in the metal remained constant at 205 p.p.m., while none was detected in the salt (limit of detectability—10 p.p.m.).

Partition Coefficients

The partition coefficients (and overall separation factors) obtained for the various elements are, as expected, favorable (Table 4). Cesium, barium, strontium, cerium, and the total rare earth fraction, whose free energies of formation of their respective chlorides exceed that of uranium, preferentially transferred to the salt phase; ruthenium, as expected, remained in the bismuth. The partition coefficients of zirconium and uranium are similar. Iodine, probably in the form of a salt, transfers preferentially to the salt phase. Appreciable transfer of polonium to the salt was observed. In general, similar results were obtained with both types of salt.

Comparison of Results with Other Data

The present data agree well with results obtained in other experiments (Tables 5 and 6)—equilibrium studies in Type 347 stainless steel loops and bench contactors, and in glass capsules. Ten-pound batches of bismuth, containing 700-800 p.p.m. uranium, zirconium, and varying concentrations of magnesium, were equilibrated with 2 lb. of fused salt in bench contactors, while 10-g. and 2-g. samples, respectively, of metal and salt were equilibrated in glass capsules.

Theoretically, the partition coefficient should vary as the $-3/2$ power of the magnesium concentration in the bismuth for trivalent atoms such as cerium, and to the -1 power for bivalent atoms, such as barium. Egan (6) has determined the activity coefficients of magnesium and cerium in bismuth at 500° C.

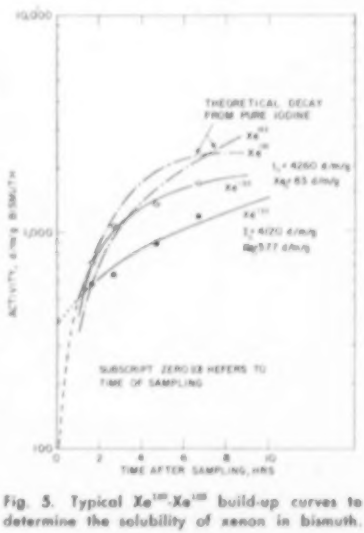


Fig. 5. Typical Xe^{135}-Xe^{133} build-up curves to determine the solubility of xenon in bismuth.

* partition coefficient = k = concentration in salt, p.p.m. / concentration in bismuth, p.p.m.

by electrolytic cell measurements. The respective values are: 2×10^{-6} and 3×10^{-6}. He has estimated the activity coefficients of $MgCl_2$ and $CeCl_3$ in fused salt to be 0.073 and 0.1, respectively.

With the use of the above values, the partition coefficient for cerium has been calculated and is shown as a function of Mg concentration in Figure 6. The present experimental results, along with others from previous studies, are shown for comparison. Values of the partition coefficients at magnesium concentrations of 75 p.p.m. and 135 p.p.m. fall on a line of the proper slope and near the calculated curve; that at 30 p.p.m. does not. Difficulty had been encountered during the first four ternary-salt-contacting runs (at a magnesium concentration of 30 p.p.m.) when it was found that salt lines appeared to be partially plugged. Since grey matter was observed also in the salt samples, there may have been a scum floating on the bismuth-salt interface which reduced the transfer of fission products to the salt. In subsequent runs, the foreign matter was apparently removed and the salt flowed freely. Several results are also presented for the partition coefficients of cerium obtained with highly purified salt in small-scale capsule equilibration experiments in the absence of uranium. All experimental results are in fairly good agreement but differ somewhat from the values calculated from activity coefficients. As might be expected, the best values are obtained in small, glass-capsule experiments.

Table 1.—Concentrations of Xenon in Bismuth and Gas at 4 lb./sq. in. gauge and 500° C.

(Samples frozen in liquid nitrogen)

	Xe^{135} (in bismuth) atoms/cc. Bi	Xe^{135} (in gas) atoms/cc. gas	Xe^{133} (in bismuth) atoms/cc. Bi	Xe^{133} (in gas) atoms/cc. gas
B-336	7.1×10^7	—	3.0×10^6	—
B-338	7.5×10^7	1.7×10^{10}	0	1.9×10^9
B-341	5.4×10^6	1.6×10^9	3.0×10^7	1.7×10^9
B-344	6.8×10^7	1.0×10^{10}	0	1.3×10^9
B-347	4.1×10^7	8.4×10^9	6.5×10^5	1.1×10^9
B-350	0	1.4×10^{10}	0	1.9×10^9
B-356	1.4×10^7	1.1×10^{10}	0	1.2×10^9
B-360	7.6×10^7	1.2×10^{10}	1.1×10^6	1.4×10^9
B-363	3.0×10^6	1.1×10^{10}	1.8×10^6	1.5×10^9
Avg.	6.6×10^7	1.1×10^{10}	1.6×10^6	1.3×10^9

Table 2.—Xenon Solubility at 1 Atmosphere Pressure

	mole fraction	Temperature °C.
B.N.L.	7.7×10^{-7}	500
Mitra and Bonilla	8×10^{-7}	492
McMillan (theoretical)	3×10^{-10}	500
McMillan (extrapolated on the basis of a positive temperature coefficient)	9×10^{-9}	500

Table 3.—Effect on Loop B Additive Concentrations of Contacting Fuel Stream with LiCl-KCl Salt at 500° C.

	Uranium		Magnesium		Zirconium	
Run	metal p.p.m.	salt p.p.m.	metal p.p.m.	salt p.p.m.	metal p.p.m.	salt p.p.m.
1	800	23.8	22	4,800	210	8
2	800	43.4	19	3,600	190	28
3	800	41.4	10	1,800	175	5
4	800	49	9	—	175	—

Table 4.—Comparison of Partition Coefficients and Over-all Separation Factors Between the $MgCl_2$-NaCl-KCl and LiCl-KCl Salts

	k		K	
	$MgCl_2$-NaCl-KCl	LiCl-KCl	$MgCl_2$-NaCl-KCl	LiCl-KCl
U	0.080 0.040 0.030	0.048		
Ce^{147}	1020 468 400	109	18700 12900 14050	2040
Ba^{140}	480 342 414	1325	7130 8400 13900	31400
$Sr^{89,91}$	125 (135 p.p.m. Mg only)	——	3430	——
Ce^{144}	3.82 3.56 3.17	7.4	62.6 91.6 94.6	137
TRE	4.07 7.35		76 169	——
Zr^{95}	0.06 0.03 0.14	0.2	0.9 0.9 4.9	495
Ru^{103}	0.9 0.9 1.9	0.4	15.4 22 49.2	8.4
I^{132}	48 235 164	144	800 5810 4900	3650
Pa^{233}	0.73 0.76 0.73	0.6	12 19 23	11

Note: Values for the ternary salt are listed for magnesium concentrations of 30 p.p.m., 75 p.p.m., and 135 p.p.m. in that order, for all elements.

k = partition coefficient = $\frac{\text{concentration in the salt, p.p.m.}}{\text{concentration in the bismuth, p.p.m.}}$

K = over-all separation factor = $\frac{k_{rare}}{k_U}$

Table 5.—Comparison of Partition Coefficients Obtained by Contacting Irradiated U-Bi with LiCl-KCl Salt at 500° C.

	partition coefficients				
	Loop B	Irradiation capsules No. L-547 (14)	Irradiation capsules No. 881 (4)	Bench contactor I. (12)	Loop C (12)
U	0.0475	0.07	0.343	0.22	0.05
Ru	1325	—	37	—	—
Sr	—	34	13	—	—
Ce	109	5	—	—	—
Ce	7.4	3	31.3	7	2
TRE	—	—	4.2	—	—
Zr	0.2	—	0.4	—	—
Ru	0.4	0.13	—	—	—

Table 6.—Comparison of Partition Coefficients Obtained by Contacting Irradiated U-Bi with MgCl -NaCl-KCl Salt at 500° C.

	Loop B		Bench contactors (8)		Glass capsules Doyle (5)		Gissell* (7)
conc. of Mg	k_{Ce}	k_U	k_{Ce}	k_U	k_{Ce}	k_U	k_{Ce}
30	3.82	0.061					23
43					35	0.30	13
53					33.2	0.39	25
60			15	0.02			
75	3.56	0.040					
108			5	0.01			
135	3.17	0.030			6.6	0.046	
169							6
211							3
375					1.64	0.003	

* No uranium used in experiments

Table 7.—Total Fission-Product Activity Found in Loop B at 500° C.

	Calculated wall deposition Bismuth system atoms.	Gas system atoms	Bulk bismuth stream* atoms	Total atoms
Cs^{137}	1×10^{13} (4)	3.3×10^{13} (1.3)	2.3×10^{15} (94.5)	2.4×10^{15}
Ba^{140}	3.4×10^{13} (29)		8.3×10^{14} (71)	1.2×10^{15}
Zr^{95}	8×10^{12} (1.5)		4.9×10^{15} (98.5)	$5. \times 10^{15}$
Ru^{106}	5.3×10^{13} (5)		9.8×10^{14} (95)	$1. \times 10^{15}$
I^{131}	1.9×10^{13} (57.5)	2.3×10^{13} (1)	1.3×10^{15} (41.5)	3.2×10^{15}
Xe^{133}	5.9×10^{13} (3.5)		2.2×10^{14} (97.5)	2.3×10^{14}
Xe^{135}	3.2×10^{13} (8.5)		3.5×10^{15} (91.5)	3.8×10^{15}
Pa^{233}	3×10^{15} (0.4)	1.4×10^{16} (0.2)	8.1×10^{17} (99.4)	8.1×10^{17}
U	1×10^{4} μg		9.1×10^{7} μg	9.1×10^{7} μg

Notes: Area in contact with bismuth—2,700 sq.in.
Area in contact with gas—1,000 sq.in.
Numbers inside parentheses denote percentage of total activity.

* Bulk blanket gas, in the case of Xe^{133} and Xe^{135}

Table 8.—Comparison of Total Concentrations of Fission Products in Loop B

	Estimated concentration* atoms/cc. Bi	Experimental results atoms/cc. Bi	Fraction of estimated concentration %
Cs^{137}	7.1×10^{13}	2.1×10^{13}	30
Ba^{140}	2.2×10^{13}	1.0×10^{13}	47
Zr^{95}	9.3×10^{13}	4.3×10^{13}	47
Ru^{106}	2.6×10^{13}	8.9×10^{12}	35
I^{131}	1.6×10^{15}	2.8×10^{14}	18
Xe^{133}	9.5×10^{13}	2.0×10^{13}	20
Xe^{135}	8.9×10^{14}	3.4×10^{14}	37
Pa^{233}	1.8×10^{14}	1.5×10^{14}	82

* Based on an estimated flux of 6.33×10^{11} neutrons/(sq.cm.)(sec.)

The loop B data for the variation of the partition coefficient of uranium with magnesium concentration correlates well with bench contactor and glass-capsule experiments (Table 6 and Figure 7).

Only cerium and uranium have been extensively investigated in equilibrium distribution studies with the ternary salt. Therefore, the partition coefficients for the other elements cannot be compared with any previous results. Nevertheless, a plot comparing the partition coefficients for the F.P.S.'s with that for uranium (Figure 8) shows that extremely favorable over-all separations were obtained.

Fission Product Deposition on Solid Surfaces

The samples were both immersed in the circulating bismuth or suspended above the bismuth in the gas space of the surge tank for periods of time ranging from 15 to 75 hr. and from 18 to 112 hr., respectively.

Upon removal of the immersed samples from the loop, only a thin layer of bismuth was observed on them (estimated at less than 0.006 inches) so that it may be assumed that the observed activity was due mainly to deposition on the solid surface. The pipe wall, bulk bismuth, and samples were at a uniform temperature of 500° C. There was no bismuth on the tubes suspended in the blanket gas. The temperature of several of these tubes was measured; and the results showed that a wall temperature as high as 490° C. will allow condensation of cesium and polonium. The tubes were suspended vertically in the gas phase, exposing a distance of 4 in. The bottom end of the tube was 2 in. above the bismuth; and the total height of the gas space above the bismuth was 6 in.

The amount of fission-product deposition on the walls of the loop was estimated on the basis of that observed on the inserted tubes, and the results are summarized in Table 7. It is seen that about half the I^{133} deposited on the container walls in contact with the bismuth, and not much more than a trace on the walls in the gas space above the surge tank. Moreover, less than 10% of the xenon and cesium was estimated to have deposited on the loop walls. Only a trace of Po appeared to have deposited on the loop walls. Of the nonvolatile fission products, barium appears to have deposited on the walls to the greatest extent, that is, about one third as much on the walls as in the bismuth; while only trace amounts of Zr, Ru, and U were found on the walls.

The quantity of fission products deposited on the samples presumably reached equilibrium in a few hours. Samples of pipe from the loop, which were in contact with bismuth for the total time of the loop operation (6,445 hr.), upon analysis showed the same fission-product concentrations as the disks. The deposition is unaffected also by the type of container material since the results obtained for Type 347 stainless steel, 2¼%Cr-1%Mo steel, graphite, and a sample of ZrC-ZrN, (78% ZrN) were similar.

The fission product iodine may have been present in the bismuth as an iodide and as such was thrown out of solution. It has been shown previously that the solubility of xenon in bismuth is extremely low and that it diffuses readily in bismuth. Most of this xenon was removed to the gas phase, and only a small part deposited on the walls. Since these values are much less than for iodine, it indicates that most of the xenon will tend to diffuse to the gas (helium) phase rapidly after its formation on the walls from iodine. Good agreement (within 40%) was obtained in an immersion sample between the Xe^{133} actually present and its extrapolated value from the I^{133} analysis. Therefore, it may be concluded that the only mechanism by which xenon appears on the system walls is by decay from iodine.

Cesium is not formed directly from fission, but only by decay from iodine and xenon. It may be inferred, therefore, on the basis of the previous discussion, that the results for Cs^{137} on the steel disks are due to deposition of its precursors. Its low activity (concentration in bismuth) yields comparatively inaccurate information. On the other hand, its relatively high vapor pressure (130 mm. at 500° C.) would explain its presence in the gas system. Since both the precursors of cesium—iodine and xenon—are themselves volatile, it is not possible to determine whether the cesium found on the tubes suspended in the gas phase itself volatilized or was the decay product of volatilized xenon, or both.

The high affinity of polonium for metal surfaces and its vapor pressure of 1.9 mm. at 500° C. would predict its deposition on pipe walls in both the bismuth and gas phases.

The large percentage of barium deposition may be due, in part, to its precursors xenon and cesium.

Corrosion Products

The variation of the concentrations of the corrosion products of stainless steel with time is shown in Figure 9. The manganese and chromium concentrations remained constant at 17 p.p.m. and 32 p.p.m. respectively. Zirconium in the bismuth depressed the rate of

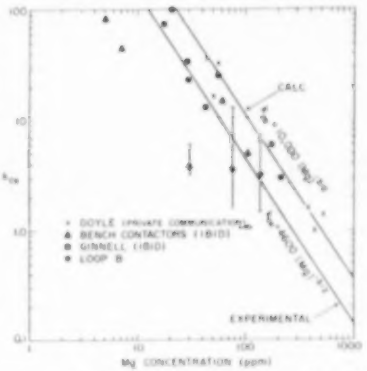


Fig. 6. Distribution of Ce^{144} between bismuth and salt ($MgCl_2$-NaCl-KCl) at 500° C.

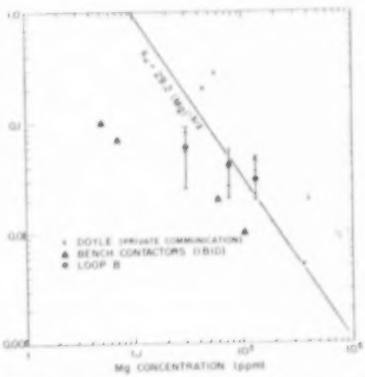


Fig. 7. Distribution of U between bismuth and salt ($MgCl_2$-NaCl-KCl) at 500° C.

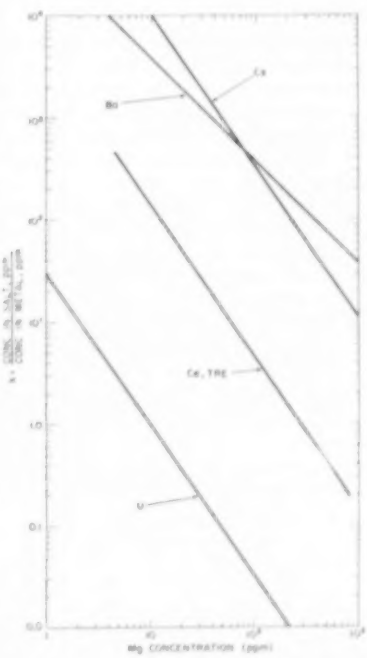


Fig. 8. Comparison of the partition coefficients of various salt-soluble fission products (FPS's) and uranium between bismuth and salt ($MgCl_2$-NaCl-KCl) at 500° C.

nickel dissolution in bismuth to the same value (4 p.p.m./10 days) as in a previous nonradioactive Type 347 stainless steel loop (*12*) operated isothermally at 500° C. The concentration of iron was erratic, but appeared to have stabilized at 75 p.p.m. This value is higher than the solubility of iron in bismuth at 500° C. and it is not known whether this was due to suspension of particulate matter. There was no noticeable effect on the corrosion of this steel due to radiation. A more definite word, however, will have to await a metallographic examination of the in-pile section.

Conclusions

EXPERIMENTAL RESULTS

The analytical procedures are described elsewhere (*13*). Good agreement was obtained for the three additives; the average deviation of the uranium results was ±7% from the mean; that for zirconium was ±5%; and that for magnesium at the low concentration of 20 p.p.m. was ±20%.

Conditions of the experiment are summarized below:

Concentration of natural uranium—800 p.p.m.

Total volume of circulating bismuth—702 cu.in.

Total volume of bismuth in neutron flux—40.2 cu.in.

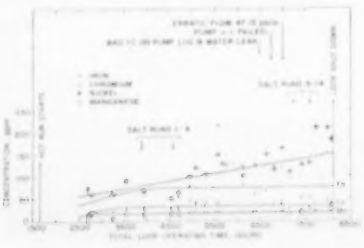
Average neutron flux (allowing for about 20% neutron attenuation through the pipe walls, etc.)—6.25×10^{11} $\frac{\text{neutrons}}{(\text{sq.cm.})(\text{sec.})}$

Fission cross section for U^{235} (taking into account the elevated graphite reflector temperature)—430 b.

Under the above conditions, the concentrations of the various fission-product nuclides were extremely low—in the range 10^{-7} to 10^{-5} p.p.m. As a result, considerably more scatter in the fission-product data was observed. This was especially true in the case of I^{138}. Relatively good precision, however, was obtained for the measurements of Xe^{133} and Xe^{135} in bismuth. Average deviations for these were ±15 and ±45% respectively.

Experimental data for the fission-product nuclide concentrations varied between 18 and 82% of the estimated values (Table 8). The total concentration of each nuclide, as indicated before, had three distinct contributions: (1) its concentration in the bulk bismuth (or blanket gas), (2) its concentration on the loop walls in contact with bismuth, and (3) its concentration on the gas system walls.

Fig. 9. Variation of the concentration of corrosion products in bismuth with time.



EVALUATION OF EXPERIMENTAL DATA

The xenon solubility in bismuth, at 500° C. and 1 atm. (xenon), was found to be 7.7×10^{-7} atom Xe/atom Bi, or approximately 0.4 p.p.m. For 1% poisoning in an L.M.F.R., the xenon concentration must be maintained at a mole fraction of 10^{-9}. This value corresponds to a partial pressure of 1.3×10^{-3} atm. in the gas phase which should not prove difficult to attain in practice. Further work, however, is required to determine the optimum conditions for xenon removal.

The partition coefficients obtained in salt contacting were extremely favorable, and agreed well with previous laboratory data. With the $MgCl_2$-NaCl-KCl eutectic, the partition coefficients (concentration in salt, p.p.m./concentration in metal, p.p.m.) were in the following ranges: U-0.03 to 0.06; Cs-400 to 1,020; Ba-342 to 480; Sr-125; Ce-3.17 to 3.82; TRE-4.07 to 7.55; Zr-0.03 to 0.14; Ru-0.9; I-48 to 235; Po-0.73 to 0.76. Similar results were obtained with the LiCl-KCl eutectic. The resulting over-all separation factors are more than adequate for engineering design purposes.

A number of fission products were found to transfer from the bismuth solution to the container walls. Unfortunately, time did not permit more extensive investigation of this problem. Additional work would definitely be required to determine the scope of this problem. This is especially true in the case of iodine and xenon, with their important effect on pile control and reactivity. The fact that iodine was observed in the gas phase and transferred to the fused salt, however, indicates the possibility of removing it (and consequently xenon also) from the U-Bi solution before it deposits on the walls of the core.

Mechanical Performance and Evaluation

A good indication of the cleanliness and tightness of the loop is the fact that the uranium concentration remained stable until the pump cell fracture occurred. There was practically no uranium on the steel walls, and uranium also remained predominantly in the bismuth during salt contacting ($k_f = 0.05$).

The majority of the equipment used in the loop proved to be satisfactory. The continuous in-pile operation of the loop for more than 6,000 hr. without requiring any direct maintenance indicates the reliability of such in-pile loops for chemical studies. The facts that alpha contamination from polonium can be controlled when the polonium is present as a dilute bismuth solution, and that repairs can be made without resorting to extreme measures, show that experiments of this type are not unduly hazardous.

The failure of all the pump cells used in the loop indicates the need to change the cell or mounting design and to locate these pumps so as to make the cells readily accessible. Besides this, no significant changes in design are believed to be necessary in future loops of the type described above.

Acknowledgment

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VOLUME REDUCTION of radioactive waste by CARRIER PRECIPITATION

A new waste-scavenging process removes cesium-137 and strontium-90 on carrier precipitates, permitting the disposal of large volumes of wastes to ground. The demonstrated ability of metal ferrocyanides to remove Cs from aqueous wastes suggests their use in a Cs recovery process.

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After pile irradiation of uranium fuel elements has taken place, it is necessary to separate uranium and the plutonium produced and to decontaminate both products from fission products produced during irradiation as well as from unwanted components of the fuel elements. Several processes (at Hanford) accomplish this separation and decontamination, all of which generate large volumes of radioactive wastes.

These radioactive process wastes may be disposed of by various means, such disposition depending on the level of radioactivity contained. Low-level wastes such as process vessel cooling water and certain condensates may be discharged to open areas and permitted to seep into the ground. Intermedite level wastes which satisfy locally established criteria with respect to contamination of ground water may be discharged to ground directly through a "crib." Acidic intermediate level wastes are made alkaline and are passed through a "cascade" of settling tanks prior to discharge of the supernatant liquid to cribs. Much of the radioactive material is carried on alkaline insoluble materials present in the wastes. A typical settling cascade is shown in Figure 1, and a typical underground crib is shown in Figure 2.

Intermediate or high-level wastes which cannot be cribbed are stored in large underground tanks. A cross section of a typical underground tank is shown in Figure 3. These tanks are expensive to build. Although the expected normal life of such tanks is long (perhaps in the range of 100 yr.), the possibility always exists of premature rupture due to unusual chemical environment, earthquakes, or bombing in the event of war. Obviously, any process modification or addition which reduces the volume of waste to be stored reduces the cost of waste handling. Also those process changes which result in ultimate storage of high-level wastes as solids rather than as liquids reduce the hazard of ground-water contamination in the event of storage-tank rupture. As discussed in the next two sections, considerable progress has been made in accomplishing both these objectives.

Reduction of Stored-Waste Volume

Several procedures have been developed, including evaporation of intermediate and high-level radioactive wastes (*3*), reuse of slightly radioactive chemicals (*4*), use of heat generated by radioactive constituents present to evaporate stored wastes (*7*), and carrier precipitation techniques which permit discharge of supernatant liquids to ground.

An evaporator arranged for batch operation is shown in Figure 4. Continuous operation is, of course, possible. For the particular waste processed in such systems, up to 70 vol. % is removable in one pass. After the concentrated waste cools and settles, about 30 vol. % of the supernatant liquid is removed on a second pass.

Major reductions in stored waste volume per unit of uranium processed are achieved by reuse of chemicals. In two solvent extraction processes, backcycling of aqueous raffinates from later cycles for use as salting agent in earlier cycles has reduced the volume of waste going to underground storage by a factor of about three. Even larger reductions are made in a process utilizing an acid as salting agent through recovery of most of the acid for reuse.

Further reduction in the volume of high radiation-level stored waste is made possible through evaporation in the storage tanks by the use of heat generated by radioactive decay of fission products (*7*). For a solvent extraction process utilizing a nonacid salting agent, a volume reduction of a factor of two has been attained, and a factor of three is anticipated. Where an acid salting agent is used and most of the acid is recovered, the volume of waste stored per unit processed may be sufficiently low to evaporate all the water present, in which case it will be necessary to replace the water for many years to maintain fluidity until nearly all of the radioactive heat generated has been dissipated.

Major reductions in the volume are also possible through scavenging techniques designed to remove the more hazardous radioactive materials from the waste followed by discharge of the decontaminated liquid to the ground.

Volume Reduction by Carrier Precipitation

In order to understand why certain moderately high level radioactive solutions can be safely discharged to ground at the Hanford site, it is necessary to consider briefly the climate and geology of the area.

The climate is semiarid; rainfall averages about 7 in./yr., most of which occurs in the winter months. Summers are hot and dry. Thus, surface conditions affect soil conditions to a depth of only a few feet.

The site was at one time a large inland lake which has been filled subsequently with alluvial sand and gravel to a depth of 250-300 ft. above the water table. In some places, remnants of a fine silt layer deposited while the region was covered with water remain above the present water table and act as a barrier toward movement of surface water to ground water. Data derived from numerous tests show that the motion of ground water toward the Columbia River is slow. Travel time, depending on the direction of flow, from the point where wastes are discharged to the Columbia River have been estimated to range from 50 to 1,500 yr. Other studies have shown that the clay fraction of the soil has good ion exchange properties and that cations of high charge (>II) are held tightly by the soil (*6*). Cations of low charge, although adsorbed, are less tightly held (*5*). Thus, wastes discharged

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Table 1.—Typical Aqueous Waste Composition

Constituent	Concentration range, moles/liter
Na^+	2.5 to 8.0
H^+	Up to 3
NO_3^-	4 to 7
PO_4^{---}	0.05 to 0.25
Fe^{+++}	Up to 0.02
Cs^{137}	10 to 100 μc/ml.
Sr^{90}	1 to 100 μc/ml.

near the surface of the ground must pass through a long (200-250 ft.) ion exchange column to reach ground water and then make a several-mile journey, taking many years to reach the Columbia River where they can come in contact with plants or animals. Under these conditions, radioactive constituents of short half-life (< 3 years) are of little concern.

Among the long-lived isotopes, only Cs^{137} and Sr^{90} exist in solution as low-charged cations. If radioactive wastes are discharged in such manner that neither Cs^{137} nor Sr^{90} reach ground water in hazardous amounts, the system is safe with respect to other long-lived nuclides. Soil column tests have shown that, if the concentration of Cs^{137} and Sr^{90} in a high salt content radioactive waste is low (< 0.1 mc./ml.), three to six column volumes of the waste can be passed through the soil before either of these isotopes appears in the effluent in an amount exceeding 0.1 maximum drinking water concentration (M.P.C.—maximum permissible drinking water concentration). It is a locally established objective that radioactive wastes shall be discharged in such manner that the ground water will not be contaminated in any place to greater than 0.1 M.P.C. in any long-lived (> 3 years) radionuclide.

One unit at Hanford produces large volumes of moderately high-level radioactive waste. Table 1 shows concentration ranges of significant constituents of the waste. The process adopted uses coprecipitation, followed by settling, to concentrate Cs^{137} and Sr^{90} in a sludge, leaving the waste solutions below cribbing limits. Economic and timing considerations required that the process:

(a) Be inexpensive, with cost for treatment and disposal less than 20 cents/gal.

(b) Use existing plant equipment.

(c) Be an operation in which necessary chemicals could be added to the waste as it is produced, the precipitates formed to settle in existing underground tanks.

(d) Have a final pH of 7.5 or greater to prevent corrosion, since the tanks have mild steel liners.

(e) Have Cs and Sr decontamination factors as high as 1,000.

(f) Permit precipitates to settle rapidly and cleanly, have a small settled volume, and be pumpable as a slurry.

These wastes contain ferric ion. When alkaline, the ferric hydroxide and phosphate mixture which precipitates carries most of the strontium present, particularly if the pH is high (>11). However, little cesium is carried. Nickel ferrocyanide is the carrier precipitate for cesium which gives the high decontamination factors required; it performs satisfactorily to a pH of 10, and at low cost.

Table 2 shows typical Cs removal efficiency of nickel ferrocyanide at various pH. High decontamination factors (>1,000), obtained at pH below 10 and the abrupt decrease in carrying pH above 10, are apparent.

Additional strontium decontamination is obtainable by addition of calcium or strontium nitrate to the waste, with calcium or strontium sulfate and/or phosphate precipitation believed responsible. Table 3 gives typical strontium decontamination data obtained with and without supplemental scavenging. Table 4 shows the dependence of strontium decontamination upon the pH with supplemental scavenging.

A schematic flow diagram (Figure 5) shows how the process is carried out in the plant. Sodium ferrocyanide and strontium nitrate are added to the acidic waste as produced. Sodium hydroxide and nickel sulfate are added continuously to the waste as it enters a large mixing and holdup tank. A continuous pH recorder-controller monitors the pH and controls the caustic addition rate to maintain the pH at about 9.5. Because the waste is not buffered in the limited operating pH range (7.5 to 10), close control of caustic addition is required. Continuous monitoring has proved a satisfactory means to obtain control of pH to ±0.5 units routinely in the plant.

The alkaline waste is then transferred to large underground tanks where the precipitates settle out. After settling, the supernatant liquid is sampled and analyzed for Cs^{137}, Sr^{90}, and other constituents of special interest in the cribbing program. Soil column tests are made to determine adsorption of Cs^{137} and Sr^{90} remaining in the supernatant liquid. Recommendations based on these data then are made on the volume of the scavenged waste which may be discharged per unit area of crib.

Supernatant liquids satisfactory for discharge to ground are decanted with a floating suction pump. Since the sludge is also pumpable, a gamma sensing device which will stop the pump if a sharp rise in gamma activity occurs is mounted on the discharge end of the pump. Extra large cribs are designed to handle the large volumes of liquid involved in this process. To insure that the entire area of a crib is covered whenever liquid is discharged to it (to prevent channeling of liquid in the soil), a flush tank similar to the flush tank on a toilet is installed in the line. This tank alternately fills at the regular pumping rate and then discharges to the crib at a rate many times the pumping rate.

Future Use of Process

So far, several million gallons of waste have been decontaminated successfully by this procedure and discharged to ground. An over-all saving

Table 2.—Effect of pH on Nickel Ferrocyanide Scavenging of Cesium

pH Before scavenging (range) (avg.)	Cs^{137} in supernatant liquid μc./ml.
	20 to 100
7	0.033
8	0.043
9	0.035
10	0.10
11	24.0
12	34.0

Table 4.—Effect of pH on Scavenging of Strontium by Addition of Nonradioactive Calcium or Strontium

pH	Sr^{90} in supernatant liquid, μc./ml.	
	Inert strontium	Inert calcium
Before scavenging (range)	20 to 100	20 to 100
7	0.54	1.8
8	0.15	1.2
9	0.09	0.38
10	0.05	0.15
11	0.08	0.15

Table 3.—Comparison of Scavenging Methods Plant Experience

pH 8 to 10

Method	Avg. residual radioactivity in supernatant liquid, μc./ml.	
	Cs^{137}	Sr^{90}
$Ni_2Fe(CN)_6$	0.057	0.82
$Ni_2Fe(CN)_6 + Ca_3(PO_4)_2$	0.026	0.22
$Ni_2Fe(CN)_6 + Sr_3(PO_4)_2$ or $SrSO_4$	0.016	0.046

of more than $500,000 has been realized to date on the process. It is anticipated that the process will be used, with modifications to account for local conditions, for the treatment and disposal of several more millions of gallons of waste, some yet to be produced and some already produced and stored before the process was developed.

Limitations

It should be pointed out that the process has definite limitations both as to the sites where it may be used and to the waste solutions for which it is applicable. The wastes after treatment still contain relatively large amounts of short-lived radionuclides, particularly ruthenium and zirconium isotopes. Also the amounts of Cs^{137} and Sr^{90} (0.1 μc./ml.) left after treatment are greatly in excess of the M.P.C. for these isotopes (1.5×10^{-3} and 8×10^{-7} μc./ml., respectively) (*2*). Therefore, the treated wastes would not be satisfactory for discharge to ground unless the combination exists of a long soil column capable of absorbing Cs, Sr, and other long-lived nuclides present and a long retention time in the ground water prior to any possible use of the ground water by plants or animals.

Use of mild steel tanks as settling basins (practiced at Hanford) limits the useful *p*H range for the process to from 7.5 to 10. Consequently, the process is not applicable without modifications to high salt solutions wherein the salt cation is insoluble in this *p*H range.

Other Use

The ability of metal ferrocyanides to remove cesium from radioactive wastes could easily be the starting point for an actual cesium recovery process. W. H. Burgus and H. W. Miller have reported at least one such process (*1*).

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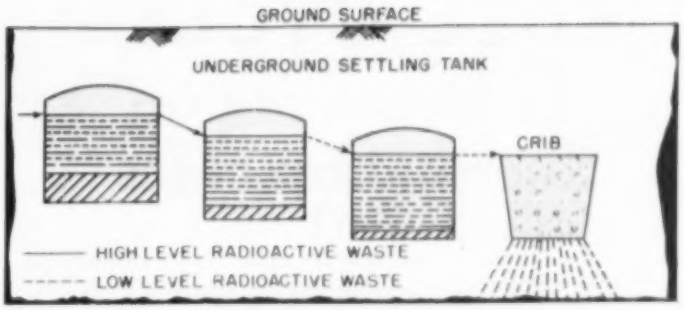

Fig. 1. Typical cascade system supernatant liquid flows to crib

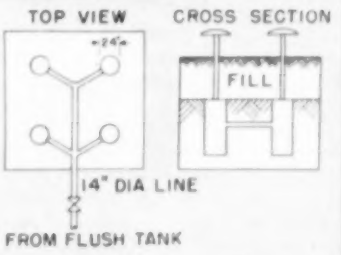

Fig. 2. Cross section and arrangement of a crib

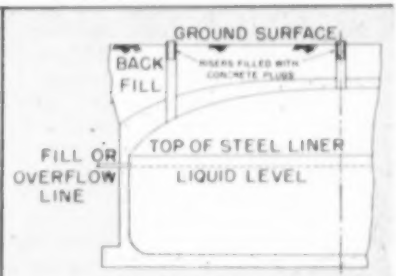

Fig. 3. Cross section of underground storage tank

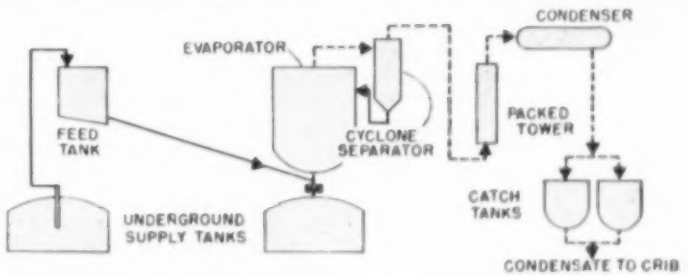

Fig. 4. Batch waste evaporator

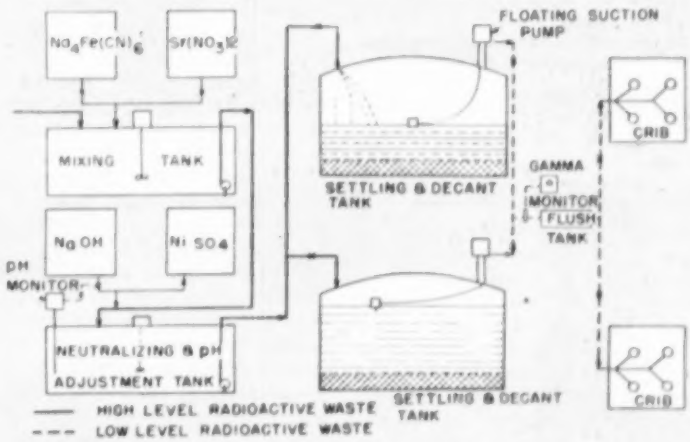

Fig. 5. Schematic flow diagram for scavenging of cesium and strontium

FUEL CYCLES
in single region thermal reactors
(Part 1)

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1. Introduction

This article is concerned with the interrelationships between a nuclear reactor and the processing plants in which its feed is prepared and its spent fuel is reclaimed.

Discussion is focused on reactors in which fissionable and fertile material is charged to a single region of a reactor, irradiated for the same length of time and processed together. In the reactor model employed it is assumed that all fissions are caused by neutrons whose energy is in the thermal or low-energy resonance region. Most of the nuclear power reactors being built today are of this single-region, thermal type. Both the uranium-plutonium and the Th-U^{233} fuel cycles are treated.

The method used in this paper for analyzing these fuel cycles is an extension of the one developed by Spinrad *et al* (*6*). Other valuable discussions of fuel cycles have been given by Dunworth (*2*), Lewis (*4*), and Weinberg (*8*).

The principal question to be investigated here is: what fraction of the fuel charged to a reactor may be caused to undergo fission before the reactor ceases to be critical? The answer to this question depends on three main factors.

1. The way the reactor and processing plant are tied together.
2. The way fuel is moved through the reactor.
3. The neutron economy of the reactor.

Each of these factors will be discussed qualitatively before methods for dealing with them quantitatively are developed.

2. Reactor Fuel Process Flowsheets

Figure 1 illustrates three ways in which a single-region thermal reactor using slightly enriched uranium as fuel may be tied into its processing plants. These flowsheets are representative of those which might be used for the sodium-graphite, boiling-water or pressurized-water reactors presently being developed in the United States. The basis for each case is production of heat in the reactor at a rate of 1,000 Mw. The fuel throughput in each case has been worked out for a consistent set of reactor parameters, so that these cases represent three different ways of operating the same reactor.

The first case represents single-pass operation of the reactor. The reactor is fed with 155 kg./day U containing 1.07% U^{235}. Spent fuel containing 0.57% U^{235} is discarded without reprocessing. To obtain the slightly enriched feed for the reactor, it is necessary to process 308 kg./day of natural uranium in a gaseous diffusion plant which strips U^{235} down to 0.36%.

The second case shows an alternative means for obtaining the slightly enriched feed for the reactor. Spent fuel from the reactor is reprocessed to recover plutonium, which is then blended with natural uranium and recycled through the reactor. This case differs from the first in the substitution of a plutonium recovery plant for a gaseous diffusion plant and in the reduction in natural uranium consumption rate to 156 kg./day, made possible by recycling plutonium.

The third case shows how the natural uranium consumption could be reduced further, to 102 kg./day, by recovering both plutonium and uranium from the spent fuel, reenriching spent fuel from 0.48% U^{235} to 0.715% in a gaseous diffusion plant, and using the uranium thus reclaimed to reduce the amount of fresh natural uranium consumed by the reactor.

The procedure for deriving the flowrates and concentrations shown in these flowsheets is the principal subject of later sections of this paper.

With the uranium-plutonium cycle ases shown in Figure 1, it is not possible to dispense entirely with some fissionable material (U^{235}) in fresh feed to the reactor system. This is because with neutrons of thermal energy it is impossible to operate the uranium-plutonium system as a breeder, since η for Pu^{239} in a thermal power reactor is less than 2.0. On the other hand, η for U^{233} in a thermal reactor is 2.31 so that a reactor system using the Th-U^{233} cycle can be operated as a breeder without requiring fissionable material in feed from external sources. A flowsheet for a reactor system operating as a breeder in the Th-U^{233} cycle is shown in Figure 2. The absence of external feed of U^{233} and the low feed rate of thorium, 1.1 kg./day, are noteworthy. Details of this flowsheet are to be discussed in Part II, Section 12.

3. Movement of Fuel Through Reactor

The principal ways in which fuel may be moved through the reactor during irradiation are as follows: batch irradiation, fuel mixed; batch irradiation, fuel unmixed; continuous irradiation, fuel mixed; and continuous irradiation, fuel unmixed.

In batch irradiation of fuel, a fresh loading of fuel is charged to the reactor and irradiated without addition or removal of fuel until the end of the irradiation cycle is reached, when the entire loading is discharged. Figure 3 represents schematically the degree of exposure of fuel at the beginning and end of batch irradiation cycles for three different cases. The numbers represent the degree of exposure of fuel and are proportional to the time integral of the neutron flux to which fuel in the indicated region of the reactor has been exposed. Case (a) represents a reactor in which the fuel is mixed, such as one whose fuel consists of a solution or suspension. In this case, every portion of the fuel is exposed to the same flux time, and has uniform composition at the end of the cycle. Cases (b) and (c) represent a reactor in which the fuel is fixed in position, such as a reactor with stationary solid fuel elements. In case (b), the flux is assumed to be uniform spatially so that the degree of exposure of every fuel element at the end of the cycle is the same, as in the mixed fuel case (a). In case (c), the flux is assumed to be nonuniform spatially; this case differs from (a) and (b) in that the degree of exposure of individual fuel elements, and their composition, varies from place to place within the reactor.

In continuous irradiation of fuel, fresh fuel is charged steadily (or intermittently at frequent intervals) and discharged steadily, both at such a rate as to keep the composition of fuel constant at every point in the reactor. Typical cases are shown in Figure 3. Case (a) represents a reactor in which the fuel is mixed; cases (b) and (c) represent reactors in which the fuel is unmixed. With continuous irradiation there is a profound difference between the mixed and unmixed cases. In the mixed case, spent fuel has the same composition as the average composition of the reactor contents. In the unmixed cases, spent fuel has been ex-

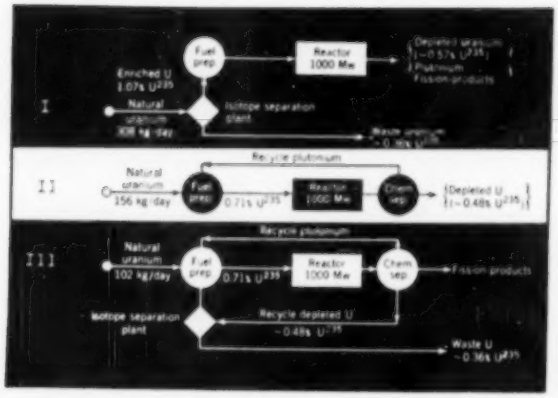


Fig. 1. Fuel process flowsheets for a one-region reactor fed with slightly enriched uranium.

Fig. 2. Fuel process flowsheet for single-region thorium breeder.

THERMAL REACTORS

Chemical engineering of nuclear processes and nuclear fuels cycles requires integration of nuclear data into unit operations and processes. Whether the problem deals with fuels in a reactor, fuels undergoing reprocessing, or the production of nuclear grade materials, the process and systems engineer requires tools by which he can determine "limits of process variables" of nuclear data in systems analysis. This paper presents techniques, methods, and procedures by which fuel cycles for nuclear reactors can be evaluated. Though the examples deal basically with single region reactors, the fundamentals and theory have application to two region systems, providing proper boundary conditions are established.

posed to a greater extent than the average reactor contents. In fact, when the average reactor contents have been exposed to the same degree in mixed and unmixed cases, the spent fuel discharged from the reactor in the unmixed, continuous case will have been exposed to about twice the extent than has spent fuel in the mixed, continuous case.

With unmixed fuel, it is possible to achieve the same distribution of exposures within the reactor with non-uniform flux; case (c), as with uniform flux; case (b), by feeding fuel through individual channels of the reactor at such rates that the exposures of fuel leaving all channels are equal. The relative lengths of arrows in case (a) indicate the relative feed rates of fuel to peripheral and central channels when the flux is higher in the center than at the edges of the reactor. Identical exposure patterns can be obtained in cases (b) and (c) if the relative variations in flux along all channels in the direction of motion of fuel are the same.

One point should be made in comparing batch and continuous exposure of mixed fuel, cases (a) of Figures 3 and 4. Even when the average flux time to which mixed fuel is exposed in the continuous case is the same as in the batch case, the composition of the fuel will not be the same since in the continuous case the fuel is a mixture of material ranging in flux-time exposure from zero to infinity, whereas in the batch case, the material has been uniformly exposed.

4. Neutron Balance

The changes that take place in fuel composition and reactivity will depend obviously on such individual terms of the reactor's neutron balance as the relative rates of absorption of neutrons by fertile and fissionable materials. For simplicity, consider a single-region, thermal reactor charged with fresh fuel of uniform composition, containing a single fissionable species, that is, U^{235}. Suppose too that the reactor has been brought to operating conditions, that fission products which reach saturation concentrations quickly (such as Xe^{135} and Sm^{149}) have reached saturation, but that no other transmutation products have been formed to a significant extent. Suppose that the reactor is just in neutron balance, without any neutrons being wasted in control rods. This condition will be called the *reference design* for the reactor.

The thermal neutron balance for the reference design is presented algebraically in Table I, and in equation form on the next page.

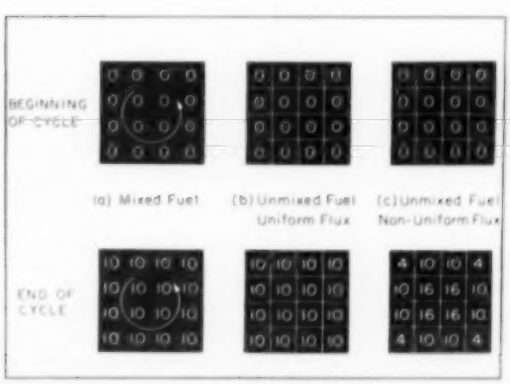


Fig. 3. Batch irradiation cases.

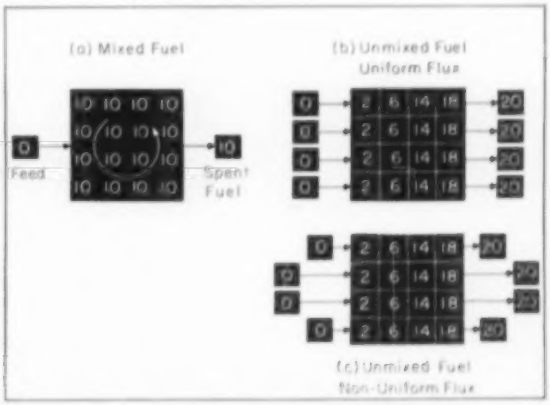


Fig. 4. Continuous irradiation cases.

Table 1.—Thermal Neutron Balance for Reference Reactor Design

Item	No. atoms per unit vol.	Thermal absorption cross section	Neutron production or consumption rate, neutrons per unit vol. per unit time
Production	N_f^*	σ_f^*	$\eta_f^* \epsilon P_{tk} p N_f^* \sigma_f^* \phi =$
Consumption			
Absorption by fissionable material	N_f^*	σ_f^*	$N_f^* \sigma_f^* \phi$
Absorption by fertile material	N_g^*	σ_g	$+ N_a^* \sigma_g \phi$
Absorption by Xe-135	N_{Xe}	σ_{Xe}	$+ N_{Xe} \sigma_{Xe} \phi$
Absorption by Sm-149	N_{Sm}	σ_{Sm}	$+ N_{Sm} \sigma_{Sm} \phi$
Absorption by coolant, moderator, structural materials, controls, etc.	N_p	σ_p	$+ \Sigma_p N_p \sigma_p \phi$
Leakage			$+ DB^2 \phi$

Table 2.—Reference Designs for Sodium-Graphite Reactor

Reactor geometry	Circular cylinder	
height, ft.	13.1	
radius, ft.	7.1	
Moderator	Graphite, pierced with holes for process tubes	
Process tube (contains fuel element and sodium coolant)	Zirconium tube, 2.00 in. I.D., 0.040 in. thick	
Lattice arrangement of process tubes	Spaced 7.0 in. on triangular centers	
Number of process tubes	536	
Average neutron temperature	400° C.	
Fissionable material, %	1 U^{235}	1.9 U^{235}
Fertile material, %	99 U^{238}	98.1 Th
Zr-clad fuel tubes, I.D., in.	0.820	0.846
O.D., in.	1.54	1.824
Mass of fissionable material, kg.	308	592
Mass of fuel, kg.	31,500	31,000
Atoms C/atom fissionable material	2980	1538
Fast fission factor, ϵ	1.027	1.000
Fission-to-resonance nonleakage probability, P_s	0.964	0.960
Fission-to-thermal nonleakage probability, P_{th}	0.954	0.954
Resonance escape probability, p	0.800	0.800

Table 3.—Effective Thermal-Neutron Properties of Nuclides for Irradiation Calculations *

	Total absorption cross section σ (barns)	Fission neutrons per absorption	Ratio of capture to fission cross section α
Th-232	4.10	0	
U-233	342	2.31	0.098
U-234	208*	0	
U-235	378	2.08	0.184
U-236	6.6	0	
U-238	1.64	0	
Pu-239	1660*	1.83	0.5734
Pu-240	2249*	0	
Pu-241	1409*	2.14	0.3454
Pu-242	19.73	0	

* The properties listed are effective values for a Maxwell-Boltzmann distribution of neutrons at 400° C. and are based upon data given in report BNL-325 (5). For U^{235} and the three plutonium isotopes there are important resonances in absorption cross section for neutrons of about 1 ev. kinetic energy. An appreciable amount of absorption occurs within these resonances with neutrons that have not become thermalized. To simplify the treatment, the effective thermal absorption cross sections for these isotopes have been increased above the true thermal values to allow for resonance-absorption of neutrons still in the slowing-down process. The relationship used was

$$\sigma_i = \bar{\sigma}_{i,\,th} + \frac{\eta_f^* \epsilon P_{th} p N_f^* \sigma_f^* \int_{E_{th}}^{E_{fission}} \sigma_i(E) dE/E}{\xi \Sigma_s} \qquad (2)$$

where $\bar{\sigma}_{i,\,th}$ is the effective thermal cross section of the nuclide in question for neutrons at 400° C. and $\xi\Sigma_s$ is the macroscopic slowing-down cross section for graphite, 0.056b.

$$\eta_f^* \epsilon P_{th} p N_f^* \sigma_f^* \phi = N_f^* \sigma_f^* \phi + N_g^* \sigma_g^* \phi + N_{Xe} \sigma_{Xe} \phi + N_{Sm} \sigma_{Sm} \phi + \Sigma_p N_p \sigma_p \phi + DB^2 \phi. \qquad (1)$$

where

η_f^* is the number of neutrons produced per thermal neutron absorbed in the fissionable species used in the reference design.

N_f^* is the effective average atomic concentration of this species.

σ_f^* is the effective absorption cross section of this species.

N_a^* is the effective average atomic concentration of the fertile species used in the reference design (that is, U^{238}).

σ_g is its effective cross section for thermal neutrons.

The other N's and σ's are effective average concentrations and effective cross sections for the other indicated species.

ϕ is the volume-average thermal flux.

Neutron-balance parameters are:

ϵ, the fast fission factor.

P_{th}, the nonleakage probability for neutrons slowing down to thermal energy.

p, resonance escape probability.

D, effective diffusion constant for thermal neutrons.

B^2, geometric buckling.

This balance equation may be applied to any portion of a single-region reactor large enough to contain a representative sample of the entire reactor contents. In a homogeneous reactor this might be unit volume; in a heterogeneous reactor it will be a region large enough to contain at least one repeating element of the reactor lattice. The N's are volume averages of atomic concentrations weighted by the relative flux in different portions of a lattice cell. The σ's are averages of cross sections weighted by the relative variation of thermal neutron flux with respect to neutron energy.

5. Reactor Examples

The analysis of fuel cycles in thermal reactors will be illustrated by reference to the sodium-graphite reactor as a typical example. Two reference designs for a reactor of this type have been worked out, one for a fresh fuel charge consisting of 1% U^{235} in U^{238}, and the other consisting of 1.9% U^{233} in thorium. These two reactor designs are summarized in Table 2. The two reactors have the same lattice structure and the same over-all dimensions. Fuel element designs have been so worked out that P_{th} and p are the same for the two reactors.

Cross sections of fissionable and fertile material, and other thermal-neutron properties, are given in Table 3. The thermal neutron balance for each of the two reference designs is given in Table 4.

6. Excess Reactivity

For an operating reactor the neutron balance will differ from Table 4 and the neutron balance equation will differ from Equation (1) because the

fuel fed to the reactor may differ from the reference fuel, and because the composition of fuel will change because of the reaction with neutrons. The general expression for the neutron balance for an operating reactor is

$$\Sigma_f \eta_f \epsilon P_{th} p N_f \sigma_f \phi = \Sigma_f N_f \sigma_f \phi + N_B \sigma_B \phi + \Sigma_h N_h \sigma_h \phi + \Sigma_p N_p \sigma_p \phi + N_B \sigma_B \phi + N_{Xe} \sigma_{Xe} \phi + N_{Sm} \sigma_{Sm} \phi + \Sigma_p N_p \sigma_p \phi + DB^2 \phi \quad (3)$$

This differs from Equation (1) in the following respects:

1. The production term on the left is now the sum of production rates from several fissionable species (such as U^{233}, Pu^{239}, and Pu^{241}) instead of the single fissionable species of the reference design.
2. The first term on the right is also a sum of the consumption rate of neutrons by several fissionable species.
3. The third term on the right, $\Sigma_h N_h \sigma_h \phi$, is new, and represents additional consumption of neutrons by nonfissionable higher isotopes such as U^{236}, Pu^{240}, and Pu^{242}, which were not present in the reference design.
4. The fourth term on the right, $\Sigma_p N_p \sigma_p \phi$, is new, and represents additional consumption of neutrons by fission products, which were not present in the reference design.
5. The fifth term on the right, $N_B \sigma_B \phi$, is new and represents additional absorption by control rods which may have to be inserted to absorb extra neutrons produced at some time during the irradiation of the fuel.

The following assumptions are to be made regarding terms in Equations (1) and (3) which remain invariant between the reference design and the operating reactor.

1. The effective cross sections, σ, remain unchanged.
2. The reactor parameters ϵ, P_{th}, P_1, p and DB^2 remain unchanged.
3. Absorption of thermal neutrons by fertile material, $N_B \sigma_B \phi$, remains unchanged.
4. Absorption of neutrons by xenon and samarium remain unchanged.

Actually, all these assumptions are slightly in error for the following reasons:

Effective cross sections of nuclides with strong resonance absorption, such as the plutonium isotopes, will change as the ratio of resonance to thermal flux changes. This ratio increases as U^{235} is burned out and Pu^{239} builds up. Also, Equation (2) neglects energy and spatial self-shielding of resonance neutrons, which becomes important as these resonance absorbers build up to appreciable concentration. The effective thermal cross section will be lower when self-shielding is taken into account. Absorption by fertile material will decrease as this material is used up; however, in most fuel cycles, fertile material is depleted by only a few per cent. Absorption by xenon and samarium will change as new fissionable species appears, because the yield of these fission products from different fissionable nuclides is different. Also, the neutron-flux level affects the concentration of Xe^{135} and may vary during constant-power irradiation. None of these effects introduces major error, and to take them into account would complicate the analysis; they have therefore been neglected in this paper.

By subtracting Equation (1) from Equation (3), it is possible to eliminate a number of terms from the neutron balance. When the resulting difference is solved for $N_B \sigma_B$ and the result is divided by $N_f^* \sigma_f^* \phi$, there is obtained:

$$\Delta = \frac{\Sigma_f (\eta_f \epsilon P_{th} p - 1) \sigma_f (N_f - N_f^*)}{N_f^* \sigma_f^*} - \frac{\Sigma_h N_h \sigma_h}{N_f^* \sigma_f^*} - \frac{\Sigma_p N_p \sigma_p}{N_f^* \sigma_f^*} \quad (4)$$

where

$$\Delta = \frac{N_B \sigma_B \phi}{N_f^* \sigma_f^* \phi} \quad (5)$$

This ratio, Δ, will be called the *local excess reactivity;* it represents the ratio of the production rate of extra neutrons in the operating reactor to the rate of absorption of neutrons by fissionable material in the reference design, both evaluated at a particular point in the reactor.

When the fuel composition is uniform throughout the reactor, as in mixed-fuel or uniform-flux cases, Δ is independent of position in the reactor, and this equation also represents the excess reactivity of the reactor as a whole. However, when the fuel composition varies from point to point, as in unmixed-fuel, nonuniform flux cases, it is necessary to compute the effective neutron balance for the entire reactor before taking the ratio expressed in (4). In the effective neutron balance for the entire reactor, each $N\sigma\phi$ term is weighted by the adjoint flux ϕ^*, which represents the importance of neutrons at a particular point in the reactor, and the term is then integrated over the entire volume of the reactor. An effective average concentration, $\overline{N}$, may be defined by

$$\overline{N}\sigma \int \phi^* \phi dV = \int \phi^* N \sigma \phi dV \quad (6)$$

In unreflected, single-region reactors the adjoint flux at a point is proportional to the actual flux, so that for such reactors

$$\overline{N} = \int N\phi^2 dV / \int \phi^2 dV \quad (7)$$

In terms of $\overline{N}$ the *average excess reactivity*, $\overline{\Delta}$, for a reactor with nonuniform composition, is given by Equation (8)

$$\overline{\Delta} = \frac{\Sigma_f (\eta_f \epsilon P_{th} p - 1) \sigma_f (\overline{N}_f - N_f^*)}{N_f^* \sigma_f^*} - \frac{\Sigma_h \overline{N}_h \sigma_h}{N_f^* \sigma_f^*} - \frac{\Sigma_p \overline{N}_p \sigma_p}{N_f^* \sigma_f^*} \quad (8)$$

because of the assumption that the concentration of fissionable material in the reference design is uniform. It also may be noted that for a single-region, unreflected reactor

$$\overline{\Delta} = \int \phi^2 \Delta dV / \int \phi^2 dV \quad (9)$$

When $\overline{\Delta}$ is positive, the reactor will be critical, with control rods partially inserted. When $\overline{\Delta}$ drops to zero, the reactor will be just critical with control rods fully withdrawn. When $\overline{\Delta}$ is negative, the reactor is subcritical and cannot be operated. No matter what changes in fuel composition take place during a fuel cycle, $\overline{\Delta}$ must remain nonnegative. Decrease of $\overline{\Delta}$ to zero in-

Table 4.—Thermal Neutron Balances for Reference Designs

Basis: one neutron absorbed by fissionable material

Fissionable material	U^{235}	U^{233}
Fertile material	U^{238}	Th
Fast neutrons from thermal fission, η_f^*	2.08	2.31
Fast neutrons from all fissions, $\eta_f^* \epsilon$	2.1362	2.3100
Resonance absorption in fertile material, $\eta_f^* \epsilon P_1 (1 - p)$	0.4117†	0.4435†
Production of thermal neutrons, $\eta_f^* \epsilon P_{th} p$	1.6304	1.7630
Absorption by fissionable material	1.0000	1.0000
Absorption by fertile material, $N_B^* \sigma_B / N_f^* \sigma_f^*$	0.4294†	0.6190†
Absorption by poisons, $\Sigma_p N_p \sigma_p / N_f^* \sigma_f^*$	0.1139	0.0676
Absorption by Xe-135 and Sm-149	0.0542	0.0542
Thermal leakage, $DB^2 / N_f^* \sigma_f^*$	0.0329	0.0222
Total consumption of thermal neutrons	1.6304	1.7630
Conversion ratio	0.8411	1.0625

† The conversion ratio is the sum of these two items.

dicates the end of the operating life of a charge of fuel. Evaluation of $\bar{\Delta}$, the average excess reactivity is, therefore, the key feature of fuel-cycle analysis.

To make use of Equation (8), it is necessary to evaluate at each point in the reactor the concentration of fissionable species N_f, higher isotopes N_h, and fission products, N_p.

The form of these concentration equations depends on the extent to which components of spent fuel is recycled and on the way fuel is moved through the reactor. The once-through flowsheet (case I of Figure 1) with unmixed fuel will be treated in the following section. The plutonium recycle flowsheet (case II or III of Figure 1) with unmixed fuel will be treated in Section 8, and the mixed fuel cases will be treated in Section 9. The Th-U^{233} reactor system will be discussed in Section 12.

7. Uranium-Plutonium System, No Recycle, Unmixed Fuel

CHANGES IN FUEL COMPOSITION DURING IRRADIATION

Consider a unit volume of fresh reactor fuel. In the once-through flowsheet (case I of Figure 1) fresh fuel will contain no U^{236}, Pu, or fission products, and will be assumed to contain N_{25}^0 atoms of U^{235} and N_{28}^0 atoms of U^{238}. The fuel is to be exposed to a thermal neutron flux ϕ, which may be a function of time t. There is to be no mixing of fuel of different composition. The variation with time of the concentration of each nuclide may be obtained from the material-balance equation for each species, as follows:

Uranium-235—The material-balance equation for U^{235} is

$$\frac{dN_{25}^{(a)}}{dt} = -N_{25}\sigma_{25}\phi(t) \qquad (10)$$

The solution of (10), subject to $N_{25} = N_{25}^0$ at $t = 0$, is

$$N_{25} = N_{25}^0 e^{-a_{25}\theta} \qquad (11)$$

where the flux-time, θ, is given by

$$\theta = \int_0^t \phi(t')dt'. \qquad (12)$$

If the fuel is moved through the reactor, $\phi(t)$ represents the flux to which the fuel was exposed at each moment of its travel. If the fuel is fixed, $\phi(t)$ represents the history of the flux at a particular point.

Uranium-236—The nonfission capture of neutrons by U^{235} results in U^{236}. The rate of change of the number of U^{235} atoms is

$$\frac{dN_{26}}{dt} = \frac{N_{25}\sigma_{25}a_{25}\phi}{1+a_{25}} - N_{26}\sigma_{26}\phi \qquad (13)$$

The solution of Equation (13), subject to $N_{26} = 0$ at $t = 0$, is

$$N_{26} = \frac{N_{25}^0\sigma_{25}a_{25}}{(\sigma_{25}-\sigma_{26})(1+a_{25})}\left[e^{-a_{25}\theta} - e^{-a_{25}\theta}\right] \qquad (14)$$

Uranium-237—The effects of U^{237} and its decay product Np^{237} will be neglected.

Uranium-238—The change in concentration of U^{238} during practical irradiation periods is of the order of only a few percent and will be neglected to simplify the equations for the plutonium isotopes.

Plutonium-239—With neglect of time lags in the decay of its radioactive precursors, the net rate of accumulation of Pu^{239} is given by:

$$\frac{dN_{49}}{dt} = \underbrace{N_{28}^0\sigma_{28}\phi}_{\text{thermal absorption in } U^{238}} + \underbrace{\eta_{25}N_{25}\sigma_{25}\epsilon P_1(1-p)\phi}_{\text{resonance absorption in } U^{238} \text{ of neutrons produced by } U^{235} \text{ fission}} + \underbrace{\eta_{49}N_{49}\sigma_{49}\epsilon P_1(1-p)\phi}_{\text{resonance absorption in } U^{238} \text{ of neutrons produced by } Pu^{239} \text{ fission}} + \underbrace{\eta_{41}N_{41}\sigma_{41}\epsilon P_1(1-p)\phi}_{\text{resonance absorption in } U^{238} \text{ of neutrons produced by } Pu^{241} \text{ fission}} - \underbrace{N_{49}\sigma_{49}}_{\text{absorption of neutrons in } Pu^{239}} \qquad (15)$$

This equation is complicated by the appearance of N_{41}, in the term representing resonance absorption of neutrons from Pu^{241}. In obtaining Equation (16) below, N_{41} has been set equal to zero. This procedure is permissible when plutonium is not recycled, because Pu^{241} then does not build up to important concentrations. In the results for plutonium recycle to be given in Section 8, the effect of this term is taken into account.

The solution of Equation (15) for the nonrecycle case, in which N_{49} is zero at $t = 0$, is:

$$N_{49} = \frac{N_{28}^0\sigma_{28}(1-e^{-a_{49}\gamma\theta})}{\sigma_{49}\gamma} + \frac{N_{25}^0\sigma_{25}a_{25}P_1(1-p)(e^{-a_{25}\theta} - e^{a_{49}\gamma\theta})}{\sigma_{49}\gamma - \sigma_{25}} \qquad (16)$$

where

$$\gamma = 1 - \eta_{49}P_1(1-p)\epsilon \qquad (17)$$

Higher Plutonium Isotopes—The differential equations for higher plutonium isotopes are

$$Pu^{240}: \frac{dN_{40}}{dt} = \frac{N_{49}\sigma_{49}a_{49}\phi}{1+a_{49}} - N_{40}\sigma_{40}\phi \qquad (18)$$

$$Pu^{241}: \frac{dN_{41}}{dt} = N_{40}\sigma_{40}\phi - N_{41}\sigma_{41}\phi \qquad (19)$$

$$Pu^{242}: \frac{dN_{42}}{dt} = \frac{N_{41}\sigma_{41}a_{41}\phi}{1+a_{41}} - N_{42}\sigma_{42}\phi \qquad (20)$$

These equations are to be solved subject to the boundary conditions that $N_{40} = N_{41} = N_{42} = 0$ at $t = 0$. The solutions are complicated and will not be given explicitly here. Solutions of these equations are given in another publication (*1*). Each is of the form:

$$N_i = N_{28}^0 v_i(\theta) + N_{25}^0 w_i(\theta), \qquad (21)$$

so that:

(1) Each concentration depends on time only through the flux-time, θ.

(2) Each concentration is a sum of two terms, the first proportional to N_{28}^0 and the second to N_{25}^0.

Fission Products—The rate of increase in concentration $\Sigma_F N_F$ of total fission-product pairs, but excluding Xe^{135} and Sm^{149}, is:

$$\frac{d\Sigma_F N_F}{dt} = \left[\frac{N_{25}\sigma_{25}}{1+a_{25}} + \frac{N_{49}\sigma_{49}}{1+a_{49}} + \frac{N_{41}\sigma_{41}}{1+a_{41}}\right]\phi \qquad (22)$$

Burn-out of fission products has been neglected. It is convenient to divide $\Sigma_F N_F$ into those fission product pairs resulting from U^{235} fission, $\Sigma_F N_F(25)$; from Pu^{239} fission, $N_F(49)$; and from Pu^{241} fission, $N_F(41)$; so that

$$\Sigma_F N_F = \Sigma_F N_F(25) + \Sigma_F N_F(49) + \Sigma_F N_F(41) \qquad (23)$$

Products of fast fission of U^{238} are ignored.

The formation rate of the products of U^{235} fission is:

$$\frac{d\Sigma_F N_F(25)}{dt} = \frac{N_{25}\sigma_{25}\phi}{1+a_{25}} \qquad (24)$$

Since fuel elements are free of fission products at the beginning of an irradiation, $\Sigma_F N_F = 0$ at $t = 0$. The

(a) The subscript 25 refers to U^{235}. The first digit is the atomic number minus 90, and the second digit is the last digit of the mass number. Notation for other nuclides are given below.

Nuclide	Notation	Nuclide	Notation	Nuclide	Notation
Th^{233}	02	U^{236}	26	Pu^{239}	49
U^{233}	23	U^{237}	27	Pu^{240}	40
U^{234}	24	U^{238}	28	Pu^{241}	41
U^{235}	25			Pu^{242}	42

solution of Equation (24) is then

$$\Sigma_F N_F(25) = \frac{N_{25}^0}{1+\alpha_{25}}\,(1-e^{-\sigma_a\phi}) \qquad (25)$$

For products of Pu^{239} fission:

$$\frac{d\Sigma_F N_F(49)}{dt} = \frac{N_{49}\sigma_{49}\phi}{1+\alpha_{49}} \qquad (26)$$

and the solution, subject to $N_F(49)=0$ at $t=0$, is

$$\Sigma_F N_F(49) = \frac{\sigma_{49}}{1+\alpha_{49}}\left\{\frac{N_{28}^0\sigma_{28}}{\gamma\sigma_{49}}\left[\theta - \frac{1-e^{-\sigma_a\gamma\theta}}{\sigma_{49}\gamma}\right] + \frac{N_{25}\sigma_{25}\eta_{25}P_1(1-p)\epsilon}{\sigma_{49}\gamma-\sigma_{25}}\left[\frac{1-e^{-\sigma_a\theta}}{\sigma_{25}} - \frac{1-e^{-\sigma_a\gamma\theta}}{\sigma_{49}\gamma}\right]\right\} \qquad (27)$$

The concentration of fission products from Pu-241 is given by a similar but still more complicated expression. The concentration of fission products from all sources is given by an equation of the form

$$\Sigma_F N_F = N_{28}^0 v_F(\theta) + N_{25}^0 w_F(\theta) \qquad (28)$$

which is of the same form as the equations for plutonium isotopes.

The term $\Sigma_F N_F \sigma_F$ enters Equation (4) for the excess reactivity. For the purposes of this paper, this term has been evaluated by

$$\Sigma_F N_F \sigma_F = 50.8\,\Sigma_F N_F \text{ b.} \qquad (29)$$

This is equivalent to assuming that the average cross sections of the products of fission of U^{235}, Pu^{239}, Pu^{241}, and U^{233} are the same and equal 50.8 b./fission.

Calculations quoted by Weinberg (8) suggest that this value is about 10% high and show that the average fission product cross section depends somewhat on the nuclide, which has undergone fission, because the fission yield distribution varies from one fissionable species to another. Weinberg also shows that burn-out of fission products causes the average cross section to decrease with the flux-time to which fission products are exposed. Since this effect has been neglected in this paper, the predicted absorption of neutrons by fission products is on the high side, and the predicted reactivity lifetime of fuel is a little low. The effect of irradiation on the effective cross section of fission products has also been studied by Walker (7).

Figure 5 shows the changes in composition that occur in fuel which at time zero consists of 1% U^{235} in U^{238}, as a function of flux-time. U^{235} concentration decreases exponentially with flux-time.

Pu^{239} increases, passes through a maximum, and then levels off. This is explained as follows:

During the early stages of the irradiation, resonance capture in U^{238} results almost entirely from neutrons generated from U^{235} fission. As U^{235} is burned out and Pu^{239} builds up, more of the fission and resonance neutrons come from Pu^{239}. Finally, as the U^{235} is further depleted, fewer fission neutrons are available for resonance capture in U^{238}, and the Pu^{239} concentration goes through a maximum at 2.3×10^{21} cm.$^{-2}$ and begins to decrease toward a steady level at which its rate of production from its own fission neutrons (neglecting those neutrons from Pu^{241}) is equal to its rate of consumption by neutron absorption.

The number of fissions experienced by U^{235} and Pu^{239} is equal to the number of fission products pairs N_F for each of these nuclides. The curves of $N_F(25)/N_{25}$ and $N_F(49)/N_{28}$ in Figure 5 cross at the maximum flux-time considered in this figure. Hence, if this fuel can be irradiated to a flux-time of 3×10^{21} cm.$^{-2}$, equal amounts of heat will have been generated from U^{235} and Pu^{239} fuels. Also, by comparing $N_F(41)/N_{28}$ with the total N_F/N_{28}, one notes that about 10% of the total heat will have been generated by Pu^{241} fissions.

CHANGES IN REACTIVITY DURING IRRADIATION

The local excess reactivity of this slightly enriched uranium fuel at any time during irradiation may be evaluated by substituting the concentration Equations (11), (14), (16), (21), and (28) into Equation (4) for the local excess reactivity. Figure 6 shows the change of local excess reactivity with flux-time for slightly enriched fuel elements of the sodium-graphite reactor. Curve 1 refers to fuel elements of the reference design case, which contain 1.0% U^{235} at time zero. The change in composition with flux-time for this case has been given in Figure 5.

At flux-time zero, the local excess reactivity for curve (1) has the value zero because this is the reference design condition. From this point, local excess reactivity increases initially because of the formation of 0.84 atoms of more reactive Pu^{239} for each atom of less reactive U^{235} consumed. The possibility of an initial increase in reactivity comes from the fact that $\sigma_f(\eta_f\epsilon P_{th}p-1)$ for Pu^{239} is appreciably greater than for U^{235}. The excess local reactivity reaches a maximum at a flux-time of around 0.3×10^{21} cm.$^{-2}$ and then begins to decrease. It drops back to zero at a flux-time of 0.67×10^{21} cm.$^{-2}$ and is negative at all higher values. This behavior is due to the leveling off of Pu^{239} concentration while U^{235} continues to decrease and fission-product poisons to build up.

Curve (2) shows the reactivity history for a fuel initially containing 1.05% U^{235}. Its reactivity is higher than that of the reference design, and does not drop to zero until the flux-time reaches 0.74×10^{21} cm.$^{-2}$.

BATCH VS. CONTINUOUS IRRADIATION

In batch irradiation, when the fuel composition is uniform through the reactor, as with mixed fuel (Figure 3, case [a]), or with unmixed fuel and uniform flux (Figure 3, case [b]), the local excess reactivity equals the average excess reactivity of the entire fuel charge in the reactor. The point at which the local excess reactivity drops back to zero represents the maximum flux-time to which fuel can be irradiated batchwise in these cases. When

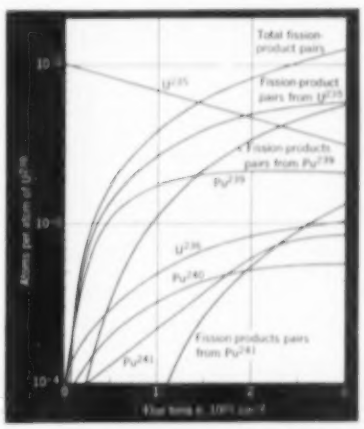
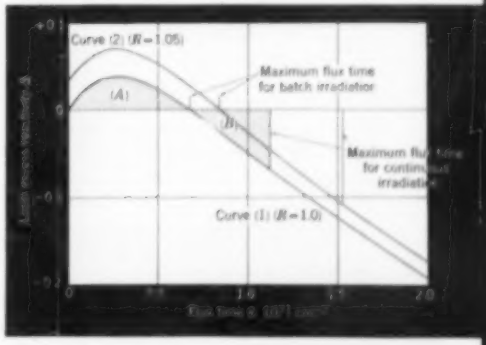


Fig. 5. Changes in fuel composition with irradiation time for fuel containing initially 1% U^{235} in uranium.

Fig. 6. Changes in local excess reactivity with irradiation time. No mixing. No plutonium recycle.



the fuel is unmixed and the flux nonuniform (Figure 3, case [c]), the fuel composition and local excess reactivity vary from point to point. To determine when the fuel will cease to support a critical reaction, it is necessary to evaluate the average excess reactivity by Equation (8).

Since the flux distribution depends on the shape of the reactor, no generally valid quantitative results can be given for this case. Since the flux is highest at the center of the reactor, a lower limit for the average flux-time to which the entire fuel charge can be irradiated is set by the flux-time at which the local excess reactivity of the fuel at the center of the reactor drops to zero.

For continuous irradiation of unmixed fuel, fuel composition and local excess reactivity vary from place to place in the reactor. When the flux is uniform and the fuel is moved through the reactor at uniform velocity such that each spent fuel element is irradiated to the same flux-time (Figure 4, case [b]), the average excess reactivity is simply the average of the local excess reactivity taken with respect to flux-time. In such a case, fuel irradiation may be extended beyond the flux-time at which the local excess reactivity drops to zero until the *average* excess reactivity has dropped to zero. In Figure 6, curve (1), this is represented by the flux-time at which shaded area (A) above the line of zero excess reactivity equals shaded area (B) below this line, or 1.12×10^{21} cm.$^{-2}$. For curve (2) this point is reached at a flux-time of 1.52×10^{21} cm.$^{-2}$. It will be noted that each of these flux-times is almost twice as great as the flux-time attainable with the same fuel for batch irradiation.

For this case of continuous irradiation with uniform flux, an algebraic expression for the average local excess reactivity can be obtained from average concentrations evaluated by

$$\overline{N} = \int_0^\tau N d\theta/\tau$$

Here τ is the flux-time to which fuel has been irradiated when discharged from the reactor.

Each of the concentration equations thus far derived is a linear combination of terms which are constant, linear in flux-time, or an exponential function of flux-time. To obtain an expression for $\overline{N}$ from the corresponding equation for N, the following substitutions should be made:

Constant term remains unchanged
θ is replaced by $\tau/2$
$e^{-a\theta}$ is replaced by $(1 - e^{-a\tau})/a\tau$.

As an example, the equation for $\Sigma_F \overline{N}_F$ (25), obtained from Equation (25) for $\Sigma_F N_F(25)$, is

$$\Sigma_F \overline{N}_F(25) = \frac{N_{28}^0}{1 + a_{25}}\left(1 - \frac{1 - e^{-\sigma_{25}\tau}}{\sigma_{25}\tau}\right) \quad (30)$$

When the flux is nonuniform, the expressions for $\overline{N}$ are more complex. Fortunately, for most cases of practical importance in which all fuel is irradiated to the same flux-time before being discharged from the reactor, it can be shown that the above substitutions are adequate approximations to the more complex exact expressions. Appendix A derives an exact expression for case (c) of Figure 4, in which the flux varies with position (x, y, z) as $\psi(x,y) \sin(\pi z/L)$.

FEED ENRICHMENT RATIO

The burn-up which may be obtained from fuel in a given nuclear reactor before the average excess reactivity drops to zero may be increased by increasing the ratio of U^{235} to U^{238} in the feed to the reactor. The feed enrichment ratio, R, is to be defined by

$$R = \frac{N_{25}^0/N_{28}^0}{N_{25}^*/N_{28}^*} \quad (31)$$

The concentrations N_{25}^0 and N_{28}^0 refer to feed for the reactor whose maximum burn-up is to be evaluated; N_{25}^* and N_{28}^* refer to the reference design.

When the maximum burn-up has been achieved with a given fuel, the average excess reactivity defined by Equation (8) will have dropped to zero. Each concentration on the right side of Equation (8) is a linear function of N_{28}^0 and of N_{25}^0 of the form of Equation (21), with coefficients that are known functions of flux-time. Hence, Equation (8), with $\overline{\Delta}$ set equal to zero, can be solved for the ratio N_{25}^0/N_{28}^0 as a known function of flux-time, and from (34), the feed enrichment ratio can be obtained in turn as a function of flux-time. The detailed equations for R as a function of flux-time are given by Benedict and Pigford (1). In this paper the result for the feed enrichment ratio R, as a function of maximum allowable flux-time for the sodium-graphite reactor now under consideration, is shown graphically in Figure 7. Curve (1) illustrates batch operation without plutonium recycle, and curve (2) continuous operation. The portion of curve (1) below $R = 1$ represents an inoperable condition in batch irradiation, and has therefore been shown as a broken line. The portion of curve (2) to the left of the minimum represents the minimum flux-time possible in continuous irradiation and has also been shown as a broken line. The marked improvement in flux-time for a given feed enrichment ratio obtainable with a given flux-time is noteworthy.

Burn-up Fraction and MwD/Ton

The maximum flux-time shown in Figure 7 has little direct physical significance. A more practical measure of the degree of irradiation is afforded by the fraction of fuel converted to fission products, the so-called maximum *burn-up fraction*. The burn-up fraction β may be evaluated by

$$\beta = \frac{\Sigma_F N_F}{N_{28}^0 + N_{25}^0} \quad (32)$$

β may be expressed in terms of the flux-time and feed enrichment ratio by multiplying numerator and denominator by $N_{28}^*/N_{25}^* N_{28}^0$, and using Equation (28) for $\Sigma_F N_F$:

$$\beta = \frac{\frac{N_{28}^*}{N_{25}^*} v_F(\theta) + R w_F(\theta)}{\frac{N_{28}^*}{N_{25}^*} + R} \quad (33)$$

A relationship between maximum burn-up fraction and feed enrichment ratio can be obtained by using Figure 7 to obtain the dependence of R on θ, and substituting associated values of R and θ into (33).

The maximum burn-up fraction and feed enrichment ratio for unmixed fuel in this sodium-graphite reactor is shown graphically in Figure 8. Curve (1) refers to batch irradiation and curve (2) to continuous irradiation, both without plutonium recycle. The maximum allowable burn-up with continuous irradiation is about twice as great as with batch irradiation for the same feed enrichment ratio. With continuous irradiation at a feed enrichment ratio of unity, a burn-up fraction of around 0.45% can be achieved; with a feed enrichment ratio of 1.5, the burn-up fraction can be increased to 2.0%.

The specific energy yield E, in megawatt days per metric ton, can be obtained from the burn-up fraction, β, the atomic weight of fuel A and the energy released per fission, 192 m.e.v., as follows:

$$E = \beta \frac{\text{atoms fissioned}}{\text{atom of fuel}} \times \frac{192 \text{ m.e.v.}}{\text{fission}} \times \frac{6.02 \times 10^{23} \text{ atoms}}{\text{g. atom}} \times 1.854 \times 10^{-24} \frac{\text{megawatt days}}{\text{m.e.v.}} \times \frac{\text{g. atom of fuel}}{\text{A g.}} \times \frac{10^6 \text{ g.}}{\text{metric ton}}$$
$$= 2.145 \times 10^6 \beta/A \text{ megawatt days/ton} \quad (34)$$

For natural or slightly enriched uranium, A ~ 238, and

$$E = 9.0 \times 10^5\, \beta \text{ Mw. days/ton} \quad (35)$$

From this relationship and Figure 8 it can be seen that fuel of the reference design composition ($R = 1$) will give an energy yield of about 2,200 Mw. days/ton in batch irradiation and around 4,100 Mw. days/ton in continuous irradiation. At 1.5 times the reference design composition, the energy yield can be increased to about 9,500 Mw. days/ton in batch irradiation and 19,000 Mw. days/ton in continuous irradiation. These estimates are based on reactivity considerations only and do not take into account possible limitations set by radiation damage.

8. Plutonium Recycle, Unmixed Fuel

CHANGES IN FUEL COMPOSITION DURING IRRADIATION

When plutonium is recycled, as in cases II and III of Figure 1, the differential equations expressing material balances for each nuclide are the same as those derived in Section 7 for the no-recycle case. The boundary conditions for U^{235}, U^{236}, and fission products are also the same, and the dependence on concentration of U^{235}, U^{236}, and fission products from U^{235} on flux-time are still given by Equations (11), (14), and (25) respectively. However, for the plutonium isotopes, the boundary conditions are no longer of the form $N_i(0) = 0$, but rather are of the form

$$N_i^0 = N_i(\tau), \quad (36)$$

where τ is the flux-time to which fuel discharged from the reactor has been irradiated.

To obtain an exact solution for the concentration of plutonium isotopes Pu^{239}, Pu^{240}, and Pu^{241}, it would be necessary to solve differential Equations (15), (18), and (19) simultaneously for N_{49}, N_{40}, and N_{41}, subject to the boundary conditions (36) on these isotopes. However, a simpler procedure of adequate precision may be used, in which advantage is taken of the fact that the concentration of Pu^{241} remains substantially constant during irradiation at its value N_{41}^0 in feed, after feed concentrations in the recycle system have reached steady values.

Equation (15) can be integrated if the value of N_{25} is substituted from (11) and the constant value of N_{41}^0 in is assigned to N_{41}:

$$N_{49} - N_{49}^0 e^{-a\omega\gamma\theta} = -C_2(e^{-a\omega\theta} - e^{-a\omega\gamma\theta}) + C_1(1 - e^{-a\omega\gamma\theta}), \quad (37)$$

where

$$-C_2 = \frac{N_{25}^0 \sigma_{25}\eta_{25} P_1'(1-p)\epsilon}{\sigma_{49}\gamma - \sigma_{25}} \quad (38)$$

and

$$C_1 = \frac{N_{28}^0\sigma_{28} + N_{41}^0\sigma_{41}\eta_{41}\epsilon P_1(1-p)}{\sigma_{49}\gamma} \quad (39)$$

When the boundary condition for complete recycle (36) is applied, there results

$$N_{49}^0 = N_{49}(\tau) = \frac{-C_2 e^{-a\omega\tau} - e^{-a\omega\gamma\tau}}{1 - e^{-a\omega\gamma\tau}} + C_1 \quad (40)$$

An equation for the plutonium^{239} concentration at any intermediate flux-time θ is then obtained by substituting (40) into (37):

$$N_{49} = C_1 - C_2\left[\frac{1 - e^{-a\omega\tau}}{1 - e^{-a\omega\gamma\tau}} e^{-a\omega\gamma\theta} - e^{-a\omega\theta}\right] \quad (41)$$

An equation for the Pu^{240} concentration can be obtained by substituting (41) into differential Equation (20), integrating, and applying the boundary condition (36). The concentration of Pu^{241}, N_{41}, is then assumed to be related to the average Pu^{240} concentration N_{40} by

$$N_{41}^0 = \sigma_{40} N_{40}/\sigma_{41}. \quad (42)$$

The result is

$$N_{41} = \frac{N_{28}^0\sigma_{28}a_{49}}{(1 + a_{49})\sigma_{41}} + \frac{C_2\sigma_{49}\gamma a_{49}\sigma_{40}\omega}{(1 + a_{49})(\sigma_{49}\gamma - \sigma_{40})\sigma_{41}\xi} \quad (43)$$

where

$$\xi = 1 - \epsilon P_1(1-p)\left(\eta_{49} + \frac{a_{49}\eta_{41}}{1 + a_{49}}\right) \quad (44)$$

$$\omega = (1 - e^{-a\omega\tau})\left[\frac{1}{\sigma_{49}\gamma} - \left(\frac{\sigma_{49}\gamma - \sigma_{40}}{\sigma_{25} - \sigma_{40}}\right)\left(\frac{1}{\sigma_{25}\tau}\right) + \left(\frac{\sigma_{49}\gamma - \sigma_{25}}{\sigma_{25} - \sigma_{40}\tau}\right)\left(\frac{1}{\sigma_{40}\tau}\right)\right] \quad (45)$$

and γ is given by (17).

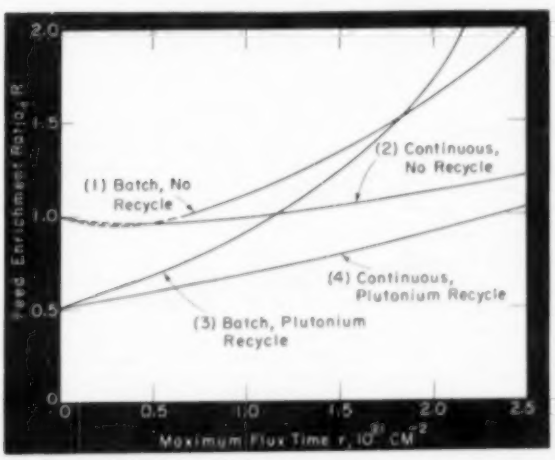


Fig. 7. Feed-enrichment ratio vs. maximum flux time for unmixed fuel.

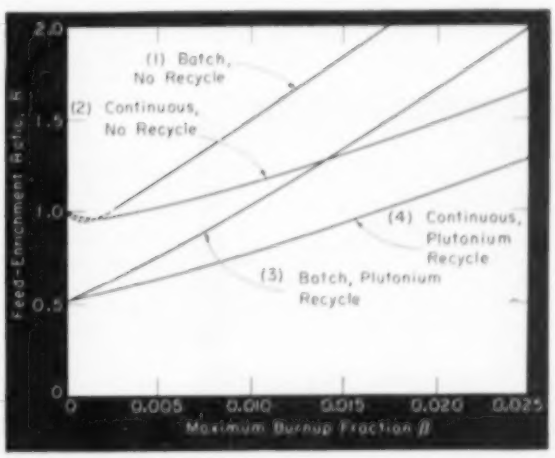


Fig. 8. Feed-enrichment ratio vs. maximum burn-up fraction for unmixed fuel.

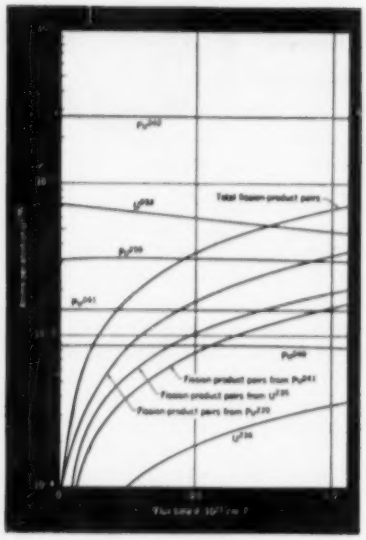


Fig. 9. Changes in fuel composition with irradiation time for plutonium recycle, natural uranium feed (continuous irradiation).

After a number of cycles of operation with plutonium recycle, Pu^{242} will approach equilibrium concentration and must be considered in the neutron balance. Its equilibrium concentration is given by:

$$N_{42} = \frac{N_{41}\sigma_{41}}{\sigma_{42}} \qquad (46)$$

Neutron capture in Pu^{242} results in Pu^{243}, which is unstable with a half life of 4.98 hr. It is assumed that the decay product, Am^{243}, is removed in the fuel reprocessing and is not recycled. Neutron capture in Am^{243} will not be considered.

The concentration of fission products from Pu^{239} is obtained by substituting (41) into (26) and integrating. The concentration of fission products from Pu^{241} is merely

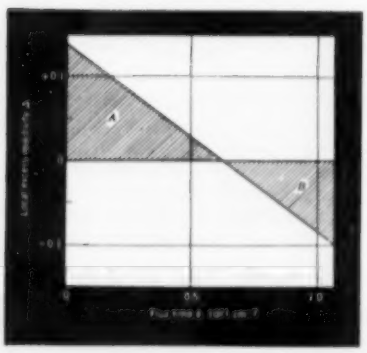


Fig. 10. Local excess reactivity as a function of irradiation time for plutonium recycle, natural uranium feed (continuous irradiation).

$$\Sigma_f N_f(41) = \frac{\sigma_{417} N_{41}^0}{1 + a_{41}} \qquad (47)$$

Since N_{41}^0 is a linear function of N_{25}^0 and N_{28}^0, so also are N_{49}, N_{40}, N_{41}, N_{42}, $\Sigma_f N_f(49)$ and $\Sigma_f N_f(41)$. Explicit equations for N_{40} and $\Sigma_f N_f(49)$ are given (*1*), together with details of the above derivation.

Since the concentration of each of the nuclides in the plutonium recycle case is a linear function of N_{25}^0 and N_{28}^0, the feed enrichment ratio which will permit operation to a given maximum flux-time can be obtained by setting the average excess reactivity equal to zero in Equation (8) and solving explicitly for N_{25}^0/N_{28}^0. The resulting complex equations are given for both batch and continuous irradiation (*1*).

FEED ENRICHMENT RATIO

The relationship between feed enrichment ratio and maximum flux-time for plutonium recycle is illustrated for the sodium-graphite reactor in Figure 7. Curve (3) refers to batch irradiation and curve (4) to continuous irradiation. The relationship between feed enrichment ratio and maximum burn-up fraction for plutonium recycle is shown by curves (3) and (4) of Figure 8. In each case, plutonium recycle permits a marked increase compared with no-recycle operation for a given feed enrichment ratio, or permits a marked reduction in feed enrichment ratio for a given maximum burnup.

With plutonium recycle, operation is possible with depleted uranium, down to a feed enrichment ratio of 0.53. With batch irradiation of natural uranium feed, at $R = 0.715$, a maximum flux-time of around 0.55×10^{21} cm.$^{-2}$ is attainable, corresponding to a maximum burn-up of around 0.39%. With continuous irradiation of natural uranium feed, a maximum flux-time of 1.07×10^{21} cm.$^{-2}$ is attainable, and the maximum burn-up is increased to around 0.71%.

PLOT OF CONCENTRATION CHANGES

Concentration changes during irradiation for natural uranium feed to to the sodium-graphite reactor, operating in continuous irradiation with plutonium recycle, are shown in Figure 9. Pu^{239} increases slightly in concentration during the early stages of the irradiation owing to resonance capture of neutrons from U^{235} fission. As U^{235} is depleted, this source of resonance neutrons becomes less important, and Pu^{239} decreases to a final concentration equal to its original concentration.

The large equilibrium concentration of Pu^{242} is due to the relatively low cross section of this nuclide. This large concentration is reached only after a number of recycle periods. Any loss of plutonium in fuel reprocessing or fuel preparation will result in a much lower equilibrium Pu^{242} concentration than has been calculated on the basis of complete recycle of plutonium.

EXCESS REACTIVITY

The local excess reactivity Δ, obtained from Equation (4), is plotted against flux-time in Figure 10 for continuous irradiation of natural uranium feed, with plutonium recycled after exposure to a flux-time of 1.07×10^{21} cm.$^{-2}$. Unlike the no-recycle case, the local reactivity decreases steadily from a positive value at zero flux-time to a negative value in spent fuel. This is due to the fact that U^{235} is being depleted and fission products are being formed during irradiation, while the plutonium concentration remains practically constant. Areas A and B of Figure 10 should be equal; the fact that B is slightly smaller than A indicates that a slightly higher flux-time than 1.07×10^{21} cm.$^{-2}$ could be obtained with natural uranium feed and plutonium recycle.

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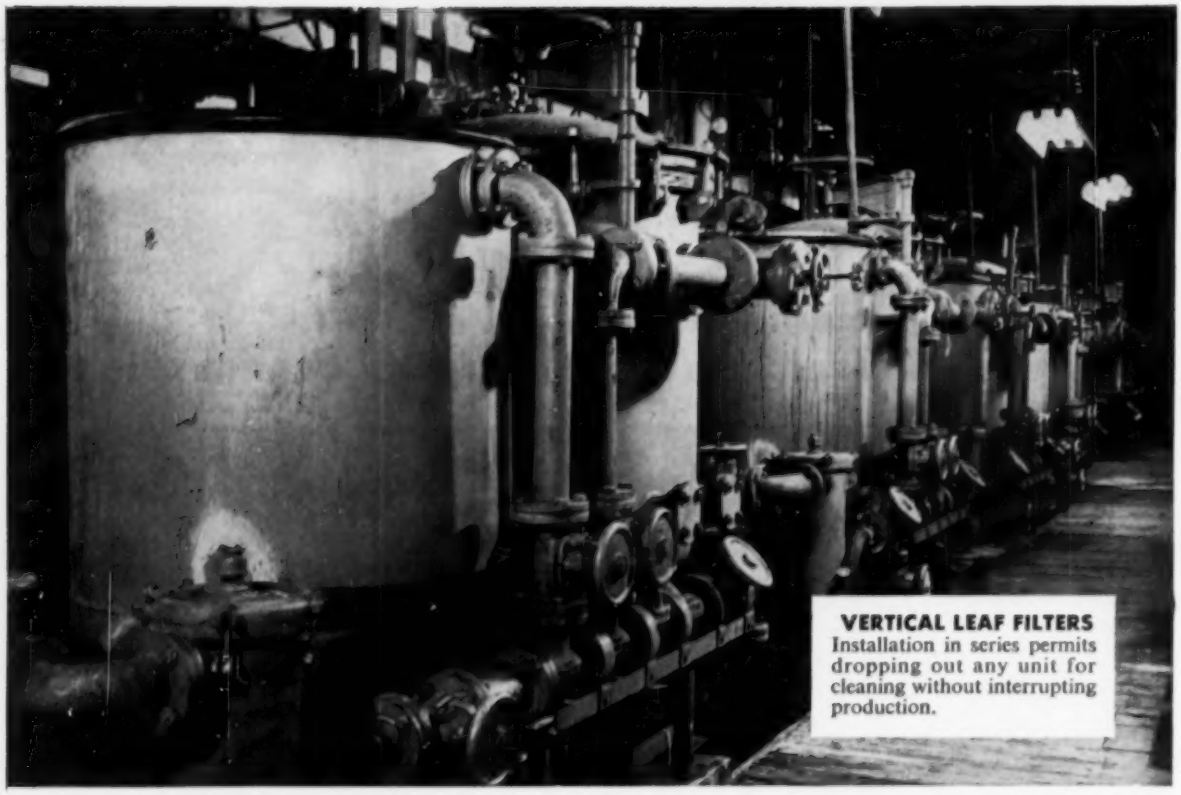
This paper is being published in two parts. The second part will appear in the March issue. It will take up reactors with mixed fuel, material flowsheets and fuel costs in reactors operating on the uranium-plutonium cycle, and reactors operating on the thorium-uranium-233 cycle.

Note: Since terms and symbols were explained throughout the text of this part, the notation is not included. It will be run in its entirety in the March issue.



VERTICAL LEAF FILTERS
Installation in series permits dropping out any unit for cleaning without interrupting production.

Looking for better filtration?

Here are the important points to consider in specifying filters for your process

Form should follow function. No one filter design efficiently handles water-thin liquids, heavy oils and viscous syrups. Rapid, thorough (and inexpensive) filtration can only be achieved by filters compatable with the process. Industrial maintains a staff of chemical engineers and chemists who work with you as a team to develop the most suitable form of the following vital factors.

Basic Design: Top, bottom or individual leaf outlets. Each has certain advantages, top outlets have a simplified lockup, controlled from outside the filter shell. Bottom outlets allow a smaller "heel" (fluid left in the chamber at end of filtering cycle) and have a "lift-out" system for attaching leaves to manifold. Individual leaf outlets permit using or shutting off any number of leaves.

Cleaning: Speed and simplified cake disposal keep downtime to a minimum. Industrial makes it possible to clean filters and handle filter cake in any way you wish.

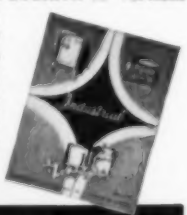
The **air wash system** injects compressed air to agitate the rinse water, allowing repeated washings without opening the filter. **Sluicing devices** direct jets against the leaves for rapid removal of filter cake. **Mechanical shakers** rapidly recover dry material through large bottom outlets or clean-out doors.

Filter Leaf Spacing. This requires a neat balance between theory and practicality, especially where large cake volumes are concerned. The speed with which a filter handles a given volume depends on the leaf area and wide spacing offers a big cake buildup; however, space and cost can limit filter size and the thicker the filter cake, the more power needed to force filtrate through it. Industrial's accumulated data on flow rates for various volumes and viscosities can help decide this tricky problem.

Auxiliary Apparatus. Piping, tanks, pumps and controls should be considered as an integrated system and are best designed and supplied along with the filter. Industrial eliminates the exasperation of buying a unit only to find the piping or pump limits the entire process. One company responsibility is insurance for a fast start and smooth running operation.

Controls. Industrial builds any degree of automation or manual control you need, from a filter that carries out an entire cycle all by itself to one with hand valves at every connection. All types of meters and indicators are available.

Why Industrial can recommend, without partiality, the filter most suitable for your needs. In addition to Vertical Filters, Industrial makes Horizontal Shell, Tubular and Hydra-Shoc Filters. All are adaptable to automation and other conveniences. **For specific information** about your filter problems, write Industrial or see our local representative. We will be glad to make analysis and recommendations.



For full data ask for Bulletin III

INDUSTRIAL

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PROCESS EQUIPMENT BRIEFS

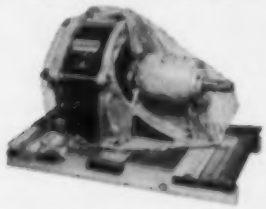
New heat exchanger sizes

A steady progression of unit capacities – in eight standard sizes having from 17.7 to 162.2 sq. ft. of heat transfer surface – is now available from stock in "Karbate" impervious graphite heat exchangers, "Series 90A" and "Series 310A". Units have interchangeable end assemblies with choice of 1, 2, 3, 4 or 5 pass arrangements.

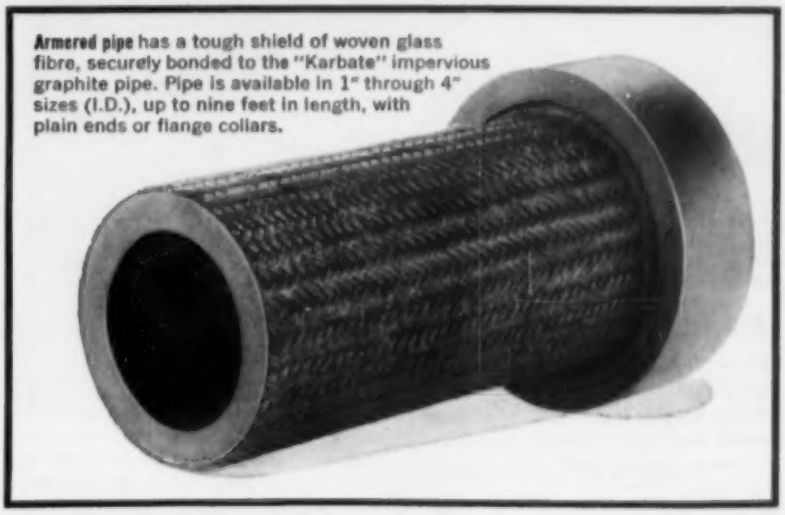
For details on these popular, low-cost corrosion-resistant units, request **Catalog Section No. S-6740.** Data on larger "Karbate" impervious graphite shell and tube heat exchangers (up to 3,585 sq. ft.) are given by **Catalog Section No. S-6800.**

Carload shipment of "Karbate" pumps

Increasing use of "Karbate" impervious graphite for transfer and circulating services is demonstrated by shipment of a carload of "Karbate" centrifugal pumps for use in rayon spin bath service. Here, where 15% H_2SO_4 at 200°F. is handled, the use of "Karbate" pumps will eliminate possibility of metallic contamination.



Packaging of "Karbate" pumps is convenient, too. Covered with vinyl film, each pump is securely anchored on a pallet and crated. Complete instructions on installation and operation are sent with each pump. For further information, ask for **Catalog Section No. S-7250.**



Armored pipe has a tough shield of woven glass fibre, securely bonded to the "Karbate" impervious graphite pipe. Pipe is available in 1" through 4" sizes (I.D.), up to nine feet in length, with plain ends or flange collars.

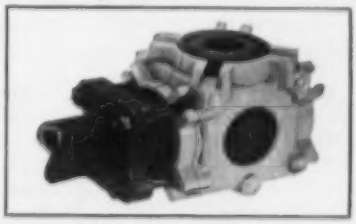
New "KARBATE" Armored Piping Gives Extra Safety with Corrosives

Greatly increased resistance to mechanical shock and strain is now a property of "Karbate" impervious graphite pipe and fittings. The reason: a newly-developed external armoring of tough, woven glass-fibre securely bonded to the pipe itself.

The most important result of this new idea in corrosion-resistant piping is the increased safety it provides in the handling of hot or corrosive liquids. In addition to increasing the resistance of "Karbate" pipe to accidental breakage, the closely-woven glass-fabric armoring remains intact even if the pipe should happen to be broken, holding line pressure . . . preventing potentially dangerous gross leakage.

Of course, this new line of "Karbate" armored pipe and fittings exhibits all the properties that have earned "Karbate" impervious graphite products wide acceptance in the chemical process industries: outstanding corrosion resistance . . . freedom from metallic contamination . . . resistance to thermal shock . . . ease of fabrication and installation.

For dimensions and other data on "Karbate" armored pipe and fittings, request **Catalog Section No S-7005.** Technical advice and assistance are also readily available.



Armored fittings have cast iron housing which not only armors the impervious graphite body but isolates it from any tensile or flexural stresses resulting from misalignment, vibration or expansion and contraction. Joint between pipe and flange collar has high strength because glass fibre sheath extends well into collar counterbore.

Adsorption a basic step in processing

Accumulated experience reveals that adsorption is a basic unit operation in chemical engineering technology. Its familiar applications include gas purification, air conditioning, solvent recovery and many other specialized uses.

Because of its enormous surface area, high porosity, low metal content and chemical inertness, the adsorbing agent is useful as a carrier for metal or metal salt catalysts and as a catalyst itself.

For a new booklet **(Catalog Section S-6450)** on the use of "Columbia" activated carbon in these applications, write National Carbon Company, 1300 Lakeside Ave., Cleveland 14, O.

NATIONAL TRADE MARK

Part of the new Celanese polyolefin plant now on-stream. Structure at right is a distillation tower. Production will be 40 million pounds of low pressure polyethylene per year.

MAJOR POLYOLEFIN PLANT ON-STREAM

New 40-million-pound-per-year polyolefin plant of Celanese Corp. goes on-stream this month near Houston, Texas. Product is "low-pressure polyethylene."

Under license from Phillips Petroleum Co., Celanese is now in major production of the new low-pressure polymer of ethylene under the trade name Fortiflex. Expected to open entirely new fields, the often-in-the-news low pressure plastic can be used in many normal polyethylene applications, will provide properties enabling it to be used in many fields now barred to polyethylene. (Products made from the new plastic will have rigidity, heat resistance, toughness and chemical inertness, will withstand prolonged exposure to live steam, will not become brittle even at 180° below zero F.)

Located on a 220-acre site near the Houston Ship Channel, the Celanese plant will ship most of its resin by water. The plant's entire production will be shipped in molding pellet form for injection and extrusion molding. Bjorn Andersen, Celanese vice president and Plastics Division general manager, expects growth and change to be an integral part of the flexible new plant. "Our current research indicates the likelihood of future modification of the basic properties of the low-pressure plastic . . . ability to modify properties will result in the development of a family of polyolefin resins."

ISOMERIZATION PROCESS USES NEW CATALYST

Iso-Kel process, recently announced by Kellogg, designed to upgrade combined streams of pentane and hexane fractions as well as natural gasolines.

Marked economic advantages to refiners are claimed by Kellogg for a new process which increases the octane quality of straight-run naphthas and natural gasolines by isomerization of the pentanes and hexanes in a single process unit (Schematic flowsheet is shown in Figure 1.)

The process produces two separate products: (1) an isopentane stream of 104.9 CFRR*+ 9 cc TEL, and (2) an isohexane stream of 89 to 92 CFRR + 3 cc TEL, depending on the feedstock. When charging light naphtha, the combined streams have an overall yield of 97 vol. % and an octane number of about 96 CFRR + 3 cc TEL. When feeding natural gasoline, overall yield is 99 vol. % and octane number of about 99.8 CFRR + 3 cc TEL.

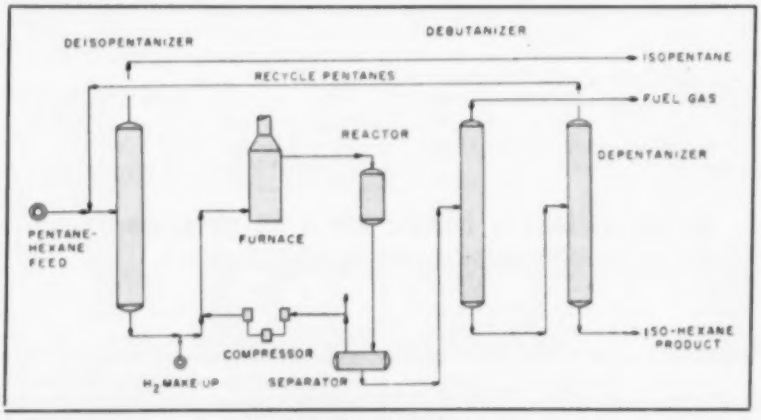
Advantages of the new process are said to rest on use of a new precious metal catalyst (not platinum) devel-

(*Continued on page* 54)

* Cooperation Fuels Research octane rating method.

Table 1.—Isomerization of Pentane-Hexane Fraction From Commercial Stocks

	Kuwait		Mid-Continent		Nat. gasoline	
	Feed	Product	Feed	Product	Feed	Product
Total C_5-C_6						
Vol. %	100.0	97.3	100.0	96.7	100.0	99.2
Octane CFRR-Clear	63.7	77.7	62.1	77.0	72.3	83.3
+3 cc TEL	88.3	96.2	87.3	95.8	93.9	99.8
Pentane Fraction						
Vol. % of Total C_5-C_6	45.0	45.0	34.5	34.5	58.5	58.5
Octane CFRR-Clear	74.4	91.0	72.9	91.0	79.2	91.0
+3 cc TEL	95.8	104.9	94.9	104.9	98.4	104.9
Hexane Fraction						
Vol. & of Total C_5-C_6	55.0	52.3	65.5	62.2	41.5	40.7
Octane CFRR-Clear	54.9	66.3	56.4	69.2	62.2	72.2
+3 cc TEL	82.2	88.7	83.3	90.7	87.5	92.4



Schematic flowsheet of Iso-Kel process.

ISOMERIZATION PROCESS

(*Continued from page 52*)

oped in Kellogg's research laboratories. The process is vapor-phase and operates in the presence of hydrogen. There are said to be no corrosive elements in the system and operating conditions are said to be less severe than those for reforming heavy naphtha.

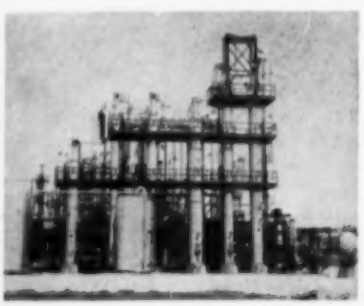
Calculated yields and quantities for processing three light naphthas of varying crude source are shown in Table 1. These calculations were based on experimental data obtained from processing pentanes and hexanes.

According to Kellogg, installation of a 3,100 bbl./day Iso-Kel unit in a 50,000 bbl./day refinery would result in a payout time of about 19 months for the new equipment. If existing equipment could be used, this payout time could, of course, be substantially reduced.

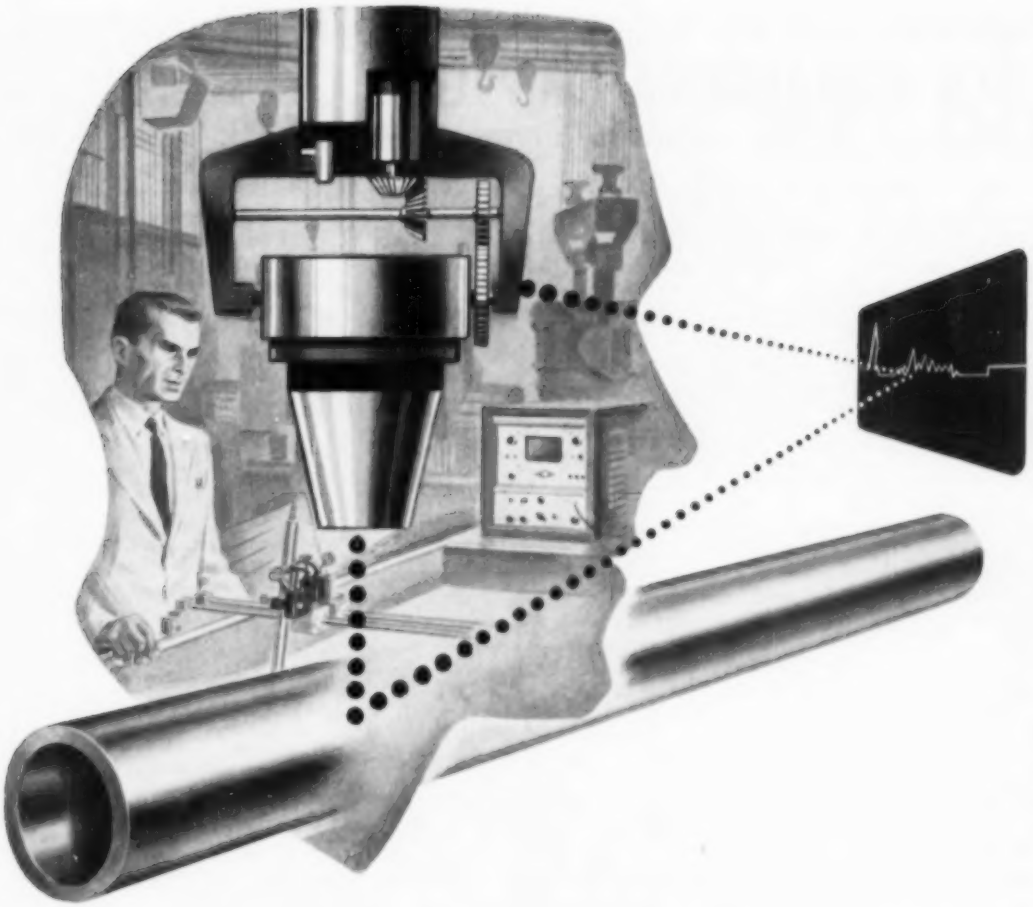
Koppers Company will design and build 174 Koppers-Becker combination coke ovens and auxiliary equipment for Inland Steel's Indiana Harbor works, East Chicago, Ind. □

A major naphthalene purification plant for Barrett Division (Allied) will be designed, engineered and constructed by Badger Manufacturing Co. Located at Barrett's Frankford, Pa., site, and the second such installation done by Badger for Barrett, it will be on-stream late in 1957. □

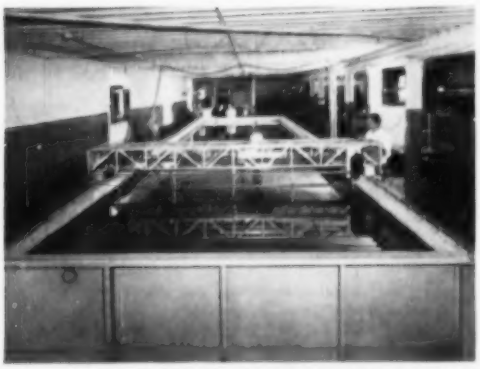
A technical service group, including specialists in all phases of operation of fertilizer plants, has been formed as part of the sales organization for agricultural chemicals in Monsanto's Inorganic Chemicals Division. □



Mono-, di-, and triethanolamines are produced from ammonia and ethylene oxide in this new unit at Olin-Mathieson's Brandenburg, Ky., plant. The ethylene oxide, along with ethylene glycol, is produced elsewhere in the Brandenburg plant from natural gas obtained from Tennessee Gas Transmission Company's trans-continental pipe line.



Finding the invisible with the inaudible



Ultrasonic Test Equipment carriage-mounted on 50-foot-long immersion tank.

An engineer once said: "With ultrasonic inspection, you're finding the invisible with the inaudible— but it's infallible."

Curtiss-Wright's Non-Destructive Ultrasonic Test Equipment uses high frequency mechanical vibrations—far beyond the range of human hearing—for precision production-quantity inspection of forgings, rolled plate, welded tubing and other metal products. The "sound head"—immersed in water —sends out vibrations that penetrate the metal under test and bounce back. Flaws show up on a cathode ray tube . . . and, simultaneously, a built-in alarm system sounds.

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What A.E.C.'s

NEW DECLASSIFICATION POLICY

means to private industry

Charles L. Marshall | Director of Division of Classification, AEC

Recently, in December, 1956, in connection with a new revision of the Tripartite Declassification Guide, a decision was reached to undertake the declassification of yet another area of restricted information. Under the new rules, vast quantities of additional information of direct concern to the civilian power reactor program can now be declassified. The information will be made available to the public on an accelerated basis by means of a second "crash program" of review and release that began in February.

This latest declassification action may be expected to have a profound effect on the development of our nuclear industry. Not only will nuclear industrial development in this country be facilitated, but the nuclear information being made available will materially aid in implementing the President's Atoms-for-Peace Plan by simplifying exchange of information with other friendly countries, and in helping to raise the standards of living in the Free World.

For the first time, it will be possible for an American engineering company to carry through a complete power reactor program, from ore treatment to fuel reprocessing, on a completely unclassified basis, using non-cleared technologists and unclassified information, even though reactor data primarily of importance to military propulsion systems and plutonium production will remain classified. Under the terms of our agreements for cooperation, and with appropriate licenses, U. S. engineering firms will now be enabled to sell and deliver complete nuclear reactors abroad and to furnish freely all the services and technical assistance which must necessarily accompany the sale and installation of such relatively new and unfamiliar equipment.

In addition to the stimulation of nuclear industry, it is hoped that the program will have important effects in the field of nuclear education and in the exchange of scientific information on an international basis.

Classification-Declassification History

To understand fully the significance of present developments in this vital field, it may be useful to recapitulate briefly the main events in the history of nuclear classification and declassification since World War II.

Early in 1946, a system was put into effect for the establishment of a declassification policy for the atomic energy program. The system also provided for the systematic review of all atomic energy information and data. The declassification policies and procedures were aimed not only at the present, but at the future as well. They provided for continuing systematic review and revision to meet the changing times.

Between 1946 and 1954 the policies were significantly revised no less than six times. In 1955, following a major revision of classification policy (the seventh revision), a special review program was conducted in Oak Ridge during which approximately 31,000 documents were reviewed and about 11,000 declassified. As a result of the program, all of the information needed for the design and construction of research reactors was released, including the nuclear data and some of the information concerning chemical processing. Remaining classified, however, was the information dealing with industrial power reactors, and the technology of chemical processing and fuel fabrication plants.

In December, 1956, the Tripartite declassification policy underwent another major revision (the eighth revision). The effects of this revision in our Declassification Guide have already been noted (see *CEP*, September, 1956). Under this new policy, the only power reactor information that will remain classified is that which is of primary importance to military propulsion or production reactors.

Crash Program Underway

To hasten the date when the newly declassified information can be physically made available to the public, a team of about 40 qualified "declassifiers" started work on February 11, 1957, at Oak Ridge in a repetition of last year's "crash program." The present project is expected to take from six to ten weeks.

The accelerated review will involve scrutiny of between 20,000 and 25,000 separate documents. Practical use of the newly-released material will be aided by the publication by the AEC of bibliographies and indexes. All of this, of course, will take time and it will be some months before the intent of the new Declassification Guide can be fully translated into reality. Most of the material has been governed by the Access Permit program under which individuals or organizations with appropriate security clearances are granted the right to obtain certain categories of classified nuclear data.

With the recent issuance of the new Declassification Guide, it has been found possible to release from security restriction almost all the non-military and non-production nuclear reactor facilities in the United States. This includes research reactors, civilian power reactors, and test and experimental reactors. (See list herewith of reactors presently declassified.) It is understood, of course, that public access to such facilities, while no longer dependent on security clearance, remains subject to authorization from the owners of the facilities.

Processing Data

Of particular interest to chemical engineers will be the release of considerable data on specific processing methods involved in the construction and operation of plants for the preparation of reactor fuel elements and the chemical reprocessing of spent reactor fuels. Detailed information can be expected to be published in the following areas:

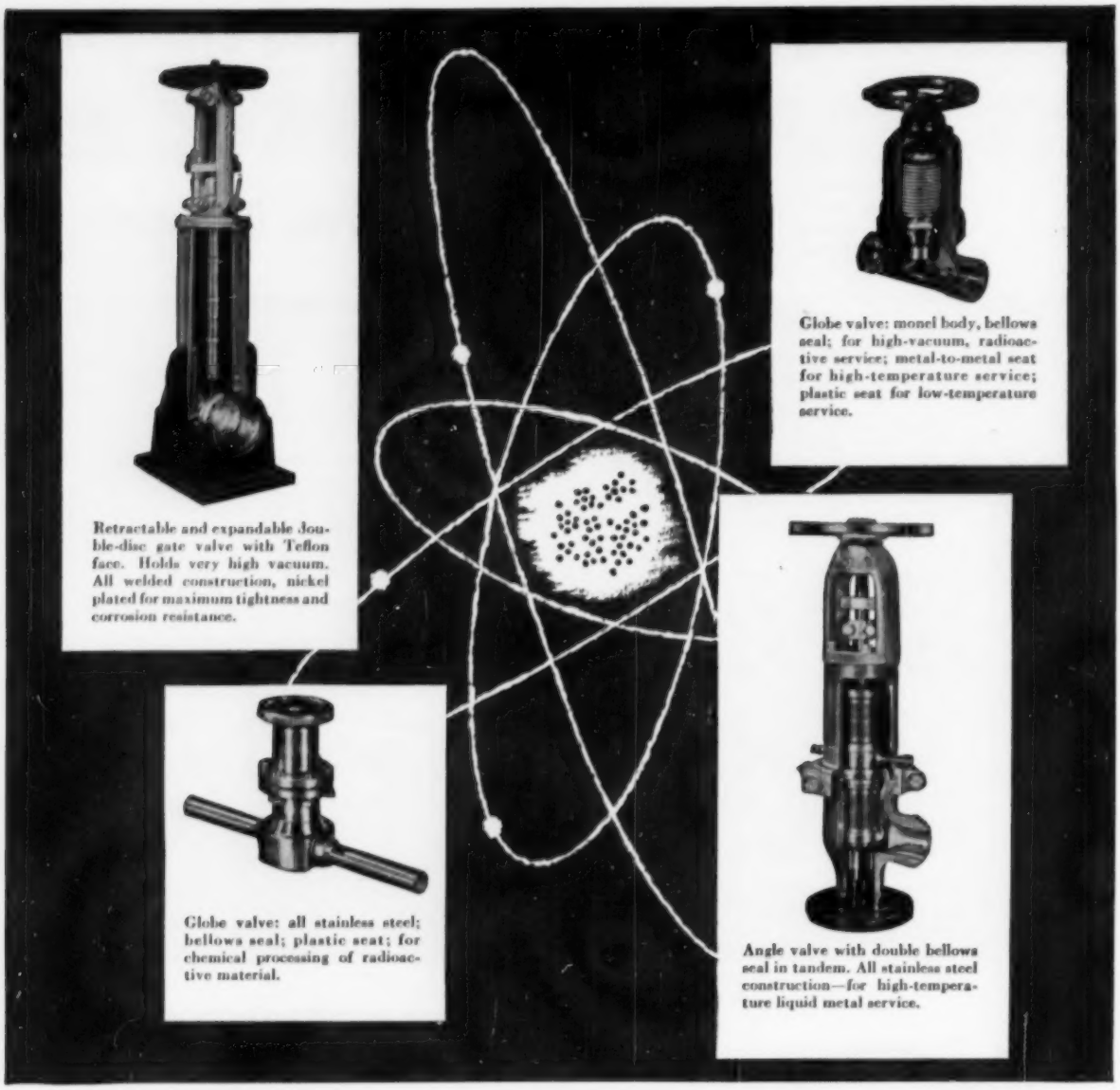
Preparation of uranium alloys.
Extraction of uranium and plutonium from spent fuel elements.
Extraction of uranium metal from compounds.
Fuel element fabrication techniques.
Metallurgy of uranium.

Under the new Guide, the remaining classified data on the dual temperature process for the production of heavy water will be released, as well as the technology involved in the liquid thermal diffusion and electromagnetic methods of separating the isotopes of uranium. Similar action is being taken on those parts of the process for separation of zirconium and hafnium that were still classified.

Furthermore, there can now be made public official figures on current ore production and estimates of total ore reserves. The world's uranium industry, which now represents a private investment of many millions of dollars, will be able to participate in planning for nuclear power development. As a major economic stabilizing influence, this decision complements the schedules published by the AEC last fall detailing the charges to be made for uranium in various degrees of enrichment and the "buy-back" prices which were established at that time for plutonium and uranium.

The effect of the new liberalized security policy will inevitably be felt not only in the industrial field, but also throughout all phases of our educational system. Existing textbooks and other teaching material dealing with nuclear subjects can now be revised and new ones can be written all the way down to the high school level. It is our hope and expectation that the resulting stimulation of interest in the scientific and technical fields will be

(*Continued on page 60*)



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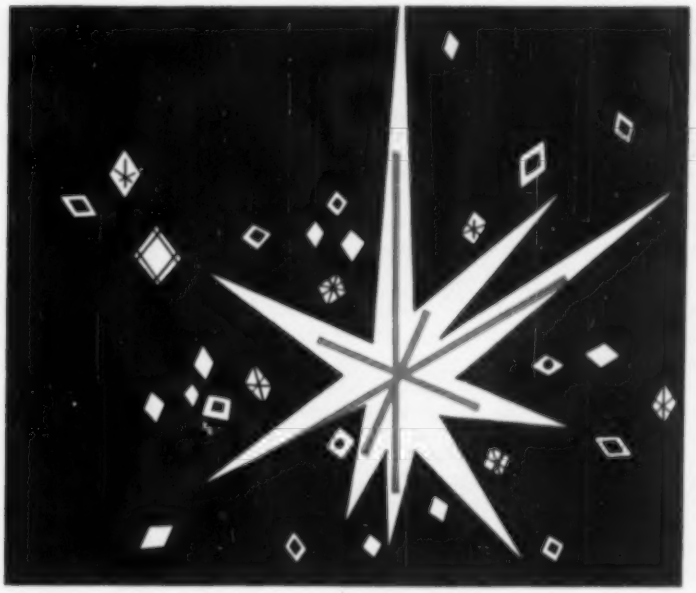

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NEW DECLASSIFICATION POLICY

(*Continued from page 56*)

an added incentive for more men and women to seek training as engineers and technicians to man our expanding nuclear energy industry. It is also our hope and expectation that the release of nuclear power information now made possible by the Commission will help to assure a better future for mankind.

DECLASSIFIED REACTORS

The following reactors have been declassified and are subject to inspection by interested parties subject to approval of the operators.

AEC REACTORS

Argonaut, Argonne Naught Power Reactor, Argonne.
BORAX-1, Boiling Reactor Experiment-1, (dismantled), National Reactor Testing Station, Idaho.
BORAX-2, Boiling Reactor Experiment-2, (dismantled), National Reactor Testing Station, Idaho.
BORAX-3, Boiling Reactor Experiment-3, National Reactor Testing Station, Idaho.
BORAX-4, Boiling Reactor Experiment-4, National Reactor Testing Station, Idaho.
Brookhaven Research Reactor, Brookhaven.
Brookhaven Medical Reactor, Brookhaven.
BSTF, Bulk Shield Test Facility, Oak Ridge.
Clementine, Los Alamos Fast Reactor (dismantled).
CP-1, (dismantled) Chicago, Illinois.
CP-2, (dismantled) Argonne National Laboratory.
CP-3, 3', (dismantled) Argonne National Laboratory.
CP-5, Argonne National Laboratory.
EBR-1, Experimental Breeder Reactor-1, National Reactor Testing Station, Idaho.
EBR-2, Experimental Breeder Reactor-2, National Reactor Testing Station, Idaho.
EBWR, Experimental Boiling Water Reactor, Argonne National Laboratory.
ETR, Engineering Test Reactor, National Reactor Testing Station, Idaho.
HEW-305, Hanford 305 Test Reactor.
HRE-1, Homogeneous Reactor Experiment-1, Oak Ridge (dismantled).
HRE-2, Homogeneous Reactor Experiment-2, Oak Ridge.
HYPO, High Power Water Boiler, Los Alamos (dismantled).
KEWB-1, Kinetic Experiment on Water Boilers, Santa Susana, California.
LAPRE-1, Los Alamos Power Reactor Experiment-1, Los Alamos.
LAPRE-2, Los Alamos Power Reactor Experiment-2, Los Alamos.
LITR, Low Intensity Test Reactor, Oak Ridge.
LIWB, Livermore Water Boiler, Livermore, California.
LMFRE, Liquid Metal Fuel Reactor Experiment.
LOPO, Low Power Water Boiler, Los Alamos (dismantled).
LPTR, Livermore Pool Type Reactor, Livermore, California.
LTR, Lattice Test Reactor (PCTR), Hanford.
MTR, Materials Testing Reactor, National Reactor Testing Station, Idaho.
Oak Ridge Graphite Reactor (X-10), Oak Ridge.
Omega West Reactor, Los Alamos.
OMRE, Organic Moderated Reactor Experiment, National Reactor Testing Station, Idaho.
ORR, Oak Ridge Research Reactor, Oak Ridge.
PCTR, Physical Constants Test Reactor (see LTR).

(*Continued on page 78*)

First High Pressure Acetylene Chemicals Plant In U.S. Now In Operation

Plant Built By Lummus For General Aniline & Film Corporation At Calvert City, Kentucky Has Been Operating Smoothly Since Startup

Early in 1956 the first full scale commercial installation in this country for the production of acetylene chemicals by high pressure techniques was placed in operation at Calvert City, Kentucky. It was engineered and constructed by The Lummus Company based on General Aniline & Film Corporation's design. GAF is the pioneer of high pressure acetylene technology in this country.

The chemicals presently manufactured include propargyl alcohol, butynediol, 1,4-butanediol, butyrolactone, pyrrolidone, vinylpyrrolidone, polyvinylpyrrolidone (PVP).

As a result of extensive research, pilot plant production and market development by GAF, these products already have wide acceptance industrially for use in cosmetics, pharmaceuticals, detergents, plastics and plasticizers, fibers, textile auxiliaries, solvents, corrosion inhibitors and germicides. With full scale commercial production now under way, industry will be able to obtain these materials at new low prices and in multi-million pound quantities.

The engineering and construction of this new and unusual processing plant required the closest cooperation between GAF and Lummus personnel at all levels, and it proceeded smoothly through a successful startup.

This project is one more indication of the ability of The Lummus Company to handle challenging installations for the chemical process industries. Look to Lummus when you have a unique engineering and construction problem.

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, N. Y. **Engineering and Sales Offices:** New York, Houston, Montreal, London, Paris, The Hague, Bombay. **Sales Offices:** Chicago, Caracas. **Heat Exchanger Plant:** Honesdale, Pennsylvania. **Fabricated Piping Plant:** East Chicago, Indiana.

CEP Data Service

DEVELOPMENTS OF THE MONTH

274 Turbo Side-Entering Propeller Mixers. First in a series of new modern designs by Turbo-Mixer, the units feature interchangeable repackable stuffing boxes or mechanical seals. They mount on standard 8" or 10" flanges, and are available either with V-belt drive or direct gear drive. Built for continuous operation with minimum maintenance. Furnished in all sizes from 1 to 30 hp.

Turbo-Mixer side-entering propeller mixers offer the following features:

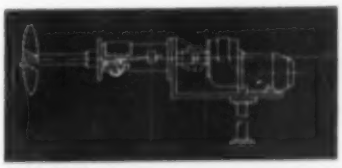
1. Repackable Stuffing Box, using specially-designed positive seal mechanism.

2. Retracting Bearing Housing. The complete housing retracts, leaving the bearings untouched.

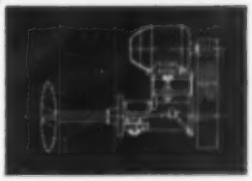
3. Simplicity. Only two bolts to retract the bearing housing and to return it to operating position.

4. A special mechanical seal can be replaced while the tank is full.

The units can be supplied in all standard materials of construction and alloys. Hardened shafts are available. For data sheet S-511, circle number 274 on Data Service Post Card on next page.



DIRECT DRIVEN



V-BELT DRIVEN

ENGINEERING DATA—MATERIALS

201 Activated Carbon. New bulletin from Barnebey-Cheney Co. describes treatment of liquid waste with Adsorbit activated carbon to remove all types of organic impurities.

202 Catalog of 2,500 Organic Chemicals. Complete stock of organic chemicals available for immediate delivery. Chicago Apparatus Co.

203 Heteropolymolybdates. 15-page bulletin covers properties, uses, classification, nomenclature, & preparation of heteropolymolybdates. Climax Molybdenum Co.

204 Vinol Polyvinyl Alcohol. Technical Bulletin PVB-44A, published by Colton Chemical Co. Division of Air Reduction Co., describes properties of vinol polyvinyl alcohol & its application to whitewares, refractories, & electronic ceramics & glazes.

205 Low Durometer Rubber Stock. New very low durometer silicone rubber stock has compressibility in the range of silicone sponge rubber. Sample & additional data available from Connecticut Hard Rubber Co.

206 Methylene Chloride-Multipurpose Solvent. 24-page booklet gives complete technical information on methylene chloride.

207 PVC Plastic Pipe Technical Data. Bulletin from Kraloy Plastic Pipe Co.

208 New Products Book. Comprehensive new book containing detailed information on the entire line of Solvay alkalies & chemicals is announced by Solvay Process Division, Allied Chemical & Dye Corp.

209 Trimethyl Aluminum. Pilot Plant quantities now available from U.S. Industrial Chemicals Co. Possible applications as polymerization catalyst and as intermediate for chemical synthesis.

210 New Vulcanizing Agent. HMDA-Carbamate, product of M. W. Kellogg, permits controlled curing of elastomers and resins capable of being cross-linked with organic polyamines. Descriptive bulletin.

211 Organic Chemicals Catalog & Price List. 224-page publication covers more than 3,500 Eastman organic chemicals. Available from Distillation Products Industries Division of Eastman Kodak Co.

(Continued on page 68)

DEVELOPMENTS OF THE MONTH (Cont.)

275 "Double-duty" Filters. A complete line of filters which can be cleaned in less than 15 minutes is being offered by the Sel-Rex Corp. The simplified cleaning operation is made possible by a new design which entails securing the entire filtering element to the hand-tightened tank cover. Thus, the complete assembly lifts out as a unit for quick, easy washing.

Any Sel-Rex filter can be used with either a specially designed stainless steel annular element or a porous stone membrane. Conversion from one element to the other takes only a few minutes.

Standard portable or stationary models are available from 250 to 18,000 gallons per hour capacity, in stainless steel with rubber lined components or with all iron parts.

Illustrated is the Model BS-1 with a capacity of 250 gallons per hour. Six catalog sheets describing these filters are available from the manufacturer, Sel-Rex Corp. (Continued on next page)

CEP Data Service

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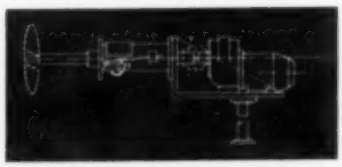

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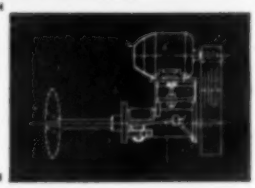

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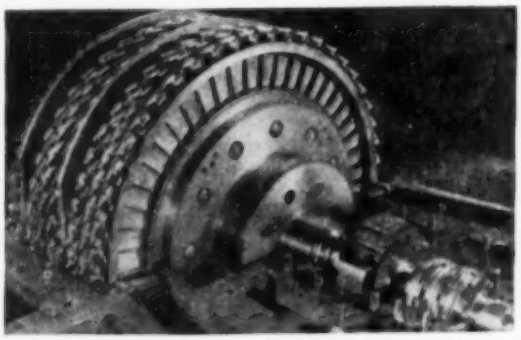

276 Adjustable-blade Axial Compressor. Allis-Chalmers has introduced a new type axial compressor with full stator blade control which can be used with almost the same capacity variation as centrifugal units and still maintain the high efficiency and pressure rises at part load points which are characteristic of the axial compressor. Each row of stator blades has a hydraulic master positioner or geared electric motors which are used to position the blades. This allows individual rows of stator blades to be adjusted separately or all can be tied together to move at one time. The new machines are particularly adapted for large volume applications where capacity variation is necessary.

(Continued on page 65)

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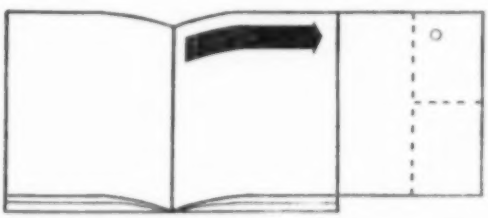

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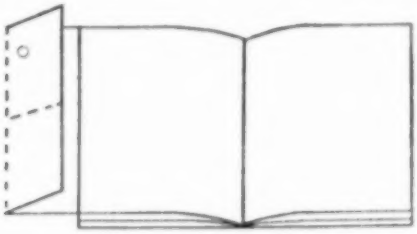

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273	274	275	276	277	278	279	280	281	282	283	284

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32A	33A	35A	36A	37A	38L	39A	40L	41A	43R	44L
45A	46A	48A	54FA	49A	50A	51A	53A	54L	55A	57A
58A	59A	60L	61A	62A	67A	69A	71A	73A	74A	76A
77A	78L	79A	81A	83A	84A	87A	88L	89A	91A	92L
93A	94L	95A	96TL	96BL	97A	99A	100TL	100BL	101A	102L
103A	104L	105A	106L	107A	108L	109A	111A	112L	112R	113R
114L	115R	116L	117R	118L	119R	120L	120R	121TR	121BR	123A
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129R	130TL	130BL	131TR	131BR	132TL	132BL	133R	134TL	134BL	
135R	138L	138BR	139TR	152TL	152BL	153BM	153TR	153BR	IBC	
OBC	201	202	203	204	205	206	207	208	209	210	211	212
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February, 1957

DEVELOPMENTS OF THE MONTH (Cont.)

277 Easy-cleaning Nozzles. The Pull-Out-Vane Fulljet Nozzle is designed for installation in inaccessible places where cleaning is a major problem. The vane of the nozzle is made with a small female threaded connection to receive a pull-out rod which can be installed by the user in the desired length. The rod extends back inside the pipe to some connection point that is easily accessible. When cleaning is needed, the vane is merely drawn back through the pipe, removed, and cleaned while the nozzle itself is flushed out. The Fulljet Nozzle is supplied in a range of sizes and capacities. Data sheet is available from Spraying Systems Co. Circle number 277 on Data Post Card.

278 New Type Flange Union. Almar Hydraulic Valve Co. offers a flange union with socket weld connections which will withstand high operating pressures (to 3,000 lb./sq.in.) for schedule 80 pipe. Special unions incorporating the same design can be provided to withstand pressures up to 10,000 lb./sq.in. Important features of the union are a true-ball seat and revolvable flanges. The true-ball seat assures leak-proof sealing even when there is a considerable misalignment of pipe. The revolvable flanges make assembly easier. Available for pipe sizes from ⅛ in. to 6 in.

279 Radially Removable Flexible Coupling. Unit which provides a simple means of disconnecting two units without axial movement of the shafts is offered by the Lovejoy Flexible Coupling Co. Completely maintenance and lubrication-free, the RRL coupling is extremely rugged and simple in design. There is no wear on the metal jaws since the load is transmitted by compression of the one-piece load cushion. Horsepower ratings range from 7.5 to 40 at 1,800 rpm. Maximum bores range from 1⅜ in. to 2¼ in. with maximum O.D.'s from 2-9/16 in. to 5 in. Maximum overall length runs from 6⅛ in. to 7⅜ in. Complete technical data from manufacturer. Circle number 279 on Data Post Card.

280 Polyester Glass Tanks. Light and heavy duty polyester glass tanks, available from Haveg Industries, have excellent resistance to the effects of brine and other corrosive solutions. They are extremely light, making for ease of installation.

The tanks can be supplied in sizes up to 30,000 gallons and are fabricated also to special requirements.

Prices are said to be substantially less than for tanks of similar size in corrosion-resistant metals.

(Continued on page 68)

PRODUCTS ADVERTISED IN THIS ISSUE

IFC Urea Plant Design & Construction. Vulcan Engineering Division offers the Inventa (Swiss) process for manufacture of plastic and pharmaceutical grade urea.

3R Bulk Feeder Data. Draver Feeders, available with automatic timing controls, prevent overloading of production machinery. B. F. Gump Co.

4A Entrainment Separators. Yorkmesh Demisters give positive separation of liquid from gas with negligible pressure drop. Bulletin from Otto H. York Co.

6A-7A Stainless Steel. Plates, heads, tube sheets, discs, forgings, flanges, rings, special patterns, bars. G. O. Carlson, Inc.

8A Sulphur Pesticide. Sulphur is an important constituent of Diazinon (product of Geigy Chemical Corp.), one of the most effective modern pesticides. Texas Gulf Sulphur Co.

9A Inert Gas Generators. For purging pipelines, tanks, etc. Bulletin from C. M. Kemp Manufacturing Co.

11A Diaphragm Control Valves. Accurate and undistorted positioning throughout entire range of valve travel. Valve data catalog. Kieley & Mueller, Inc.

12L Teflon Mechanical Seal. Chemiseals, with pressure-balanced bellows design, pay off in longer trouble-free life. United States Gasket Co. Bulletin.

13A Gas Generating Systems. Gas Atmospheres, Inc. are designers of gas generating systems for food processing, petroleum, chemicals, metals.

14A-15A Standard End Suction Centrifugal Pumps. More than 70,480 combinations from standard, stocked parts. Bulletin from Worthington Corp.

16L Differential Pressure Transmitter. Barton Model 214 differential pressure transmitter gives accurate, dependable performance in precise measurement of flow, liquid level, differential pressure. Bulletin. Barton Instrument Corp.

17A Carbon Anodes. Great Lakes Carbon Corp. offers specialized consulting services.

18A Pressure Centrifuge Data. Merco Pressure Centrifuge, product of Dorr-Oliver, is designed for continuous operation at pressures up to 110 lb./sq. in. Bulletin.

19A Nuclear Engineering Projects. Electric power, propulsion, radiation research, industrial process heating, control & safety, chemical manufacture. Ralph M. Parsons Co.

20A Chemical Process Equipment. All types of process equipment in titanium & glassed steel. Technical data from the Pfaudler Co.

23A Filters. Large cake capacity is of particular importance for economy in heavy duty filtering. Sparkler Manufacturing Co.

25A Petrochem-Isoflow Furnaces. More than 1,500 now in satisfactory service. Petro-Chem Development Co.

26L Controlled-Humidity Air Conditioning. Two technical bulletins from Niagara Blower Co.

27A "Votator" Continuous Processing Equipment. Agitates and simultaneously heats or cools liquid or viscous material. Consulting services offered by the Girdler Co.

28L Heat Exchangers. Heliflow exchangers give higher rate of heat transfer, closer temperature approach. Graham Manufacturing Co.

29A Stainless Steel Manual. 44-page booklet "Making the Most of Stainless Steels in the Chemical Processing Industries." Crucible Steel Co. of America.

30L Small-Scale Laboratory Equipment. "Mini-Lab" line, made by Ace Glass, Inc., has been expanded to include many more individual components and new assemblies. "Supplement A" available.

31A Nozzle Type Relief Valve. High performance & long service. Bulletin from Crosby Valve & Gage Co.

32A Filtration Research Service. Eimco Corp. has facilities to test your slurry on all types of filtration equipment.

33A Vinyl Resins. Exon 468 is specifically formulated for makers of vinyl asbestos floor tile. Consulting services. Chemical Sales Division, Firestone Plastics Co.

35A Liquid Sodium Pump. World's largest liquid sodium pump features many design "firsts." Byron Jackson Pumps.

36A Leakproof Pumps. Chempump can't leak because it has no seals, no stuffing box, no packing. Details from Chempump Corp.

37A Expansion Joints. Adsco expansion joints cause less heat loss & pressure drop, take up less space than pipe bends, at less cost. Adsco Industries, Inc. Bulletin.

38L Cooling Tower Fans. Bulletin from the Marley Co. describes advantages of Multi-Blade Aerfoil Fans.

39A Continuous Calciner & Cooler. Operates from 900° to 2,100°F. in reducing, oxidizing, or neutral atmosphere; cools, discharges at 200°F. or lower. Bartlett-Snow.

40L Corrosion-Resistant Plastic Piping. Technical bulletin from American Hard Rubber Co. gives properties of Ace "Riviclor" unplasticized polyvinyl chloride process piping.

41A-42A Medium-Density Polyethylene. Expansion of U. S. Industrial Chemicals Co. plant in Tuscola, Ill. described in reprint from U.S.I. Chemical News.

43R Industrial Wire Cloth. In 9 weaves in any metal or alloy, in bulk or fabricated parts. 80-page catalog from Cambridge Wire Cloth Co.

44L Rare Earth Data Sheets. Characteristics of oxides, metals, salts. Michigan Chemical Corp.

45A Liquid Level Control Equipment. Fisher Governor Co. specializes in the solution of tough liquid level control problems.

46A Process Equipment Fabrication. Heat exchangers, steel and alloy plate, containers, & pressure vessels. Bulletins from Downingtown Iron Works, Inc.

48A Design, Engineering, Fabrication Services. Process equipment in all ferrous and non-ferrous metals. Acme Coppersmithing & Machine Co.

49A Turbo-Mixers. Consulting services offered on your heavy-duty mixing problems. Turbo-Mixer Division of General American Transportation Corp.

50A Filters. Industrial Filter & Pump Mfg. Co., will send specific information on vertical, horizontal shell, tubular, & Hydra-shoc filters.

51A Impervious Graphite Equipment. Technical catalogs from National Carbon Co. on "Karbate" heat exchangers, pumps, armored piping.

53A Convertible Flow Transmitters. "TransiTwins," product of Brooks Rotameter Co., are convertible—either electric or pneumatic. Bulletin.

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54-FA Packaged Fume Washer. Made in four standard models with capacities from 750 to 6,500 cu.ft./min., the Cyclonaire is much smaller than usual custom-built units. Data from U. S. Stoneware.

54L Chemically-Inert Bellows. Teflon bellows in wide range of designs for metering pumps, pressure accumulators, batching scale connectors, etc. Catalog from Crane Packing Co.

55A Ultrasonic Inspection Systems. Complete details on quality control by ultrasonic inspection available from Curtis-Wright Corp.

57A High-pressure Pumps. Ingersoll-Rand high-pressure pumps have been in service at the Katy cycling plant for thirteen years without opening the casings. Consulting services.

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(Continued on page 72)

INSIDE STORY:

Why a Heat Exchanger Poses for an X-ray

This technician is giving a clean bill of health to a completed weld on a P-K heat exchanger. Like the x-ray of your chest, this x-ray picture is designed to pick up flaws before they have a chance to become harmful.

Pinholes, lamination, slag inclusions, and all other symptoms of failure are ruled out by this process, which is used to scrutinize the "inside" of *every weld*. Such radiographs are indispensible in manufacturing pressure vessels that will meet every test of time and use. Each x-ray is checked by a representative of the Hartford Steam Boiler Inspection and Insurance Company —for further insurance that every P-K heat exchanger meets or exceeds the rigid standards of the 1952 ASME Code for Unfired Pressure Vessels.

But weld x-rays at P-K represent only a *precaution*. They don't speak for the fact that all P-K welders are ASME qualified for a total of more than 50 types of welding procedures—meaning that the likelihood that flaws will occur at all is minimized. Nor can you see in an x-ray photo the incredibly careful design and calculation that goes into every P-K pressure vessel, to assure that it will be *thermally* and *physically* correct in every way.

Add this all-important knowledge of thermal design to P-K's fabricating and testing procedures, and you have what makes P-K heat transfer equipment different —and better—than all the rest.

Like proof? We'd be delighted to receive your inquiry. The Patterson-Kelley Co., Inc., 1720 Hanson Street, East Stroudsburg, Penna. Offices in principal cities.

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Chemical and Process Division

Twin Shell Blenders • Autoclaves • Pilot Plants • Heat Exchangers • Ribbon and Double Cone Blenders • Lever Lock Doors

MATERIALS (*Cont.*)

212 Silicone Lubricant Brochure. Properties and performance of silicone oils, greases and compounds. Much technical data in simplified tables and graphs. Dow Corning Corp.

214 Corrosion-Resistant Plastic Liner. Epoxy base compound, Coroline 347, is inert to organic acids, dilute mineral acids, caustics, alkalines, and most solvents. Technical data from Homalite Corp.

215 High-Speed Flocculating Agent. Two new booklets describe latest results in water, waste, and sewage treatment with Separan 2610, product of Dow Chemical Co.

216 Tertiary-Alkyl Primary Amines. 36-page booklet describes physical and chemical properties, applications and chemical reactions of t-butylamine, t-octylamine, Primene 81-R and Primene JM-T. Rohm & Haas Co.

217 Colored Gaskets and Shims. Instant selection of correct gauge of gasket, shim, spacer, or washer by the Color-Plast system. Four-page folder from General Gasket, Inc.

218 High Molecular Weight Polymeric Plasticizer. Emery 3049-S, product of Emery Industries, permits easy processing in conventional equipment. Technical data.

219 Chlorine Dioxide Bleaching Data. New 12-page booklet discussing bleaching of inedible fats with chlorine dioxide. Industrial Chemicals Division, Olin Mathieson Chemical Corp.

220 Titanium Trichloride. Potential application as catalyst in manufacture of isotactic polymers such as polypropylene. Available on semi-commercial basis. Preliminary technical bulletin. Stauffer Chemical Co.

221 Industrial Insulation Catalog. Standard sizes, thicknesses, and thermal conductivities for more than 20 types of heat and cold insulations for equipment and piping. Baldwin-Hill Co.

222 Chemical Catalog. Lists over 4,000 chemicals including fine organics, inorganic reagents, indicators, etc. Matheson, Coleman, and Bell.

223 Quarternary Ammonium Salts. Chemical and physical characteristics with applications and formulations. Booklet from Chemical Division, Armour and Co.

224 Handy Insulation Estimation Chart. Converts gallon quantities into sq. ft. of surface area for cylindrical vessels. Armstrong Cork Co.

225 Nonyl Alcohol—Dinonyl Phthalate. Commercial quantities now available from Eastman Chemical Products. 9-page technical data report.

226 Industrial Ceramics Selection Chart. Gives mechanical, physical, and electrical properties of Star ceramics. Star Porcelain Co.

227 Chemical Pump Packing. Self-forming chemical-resistant packing excellent for emergency use against industrial acids, alkalies, and solvents. Technical data available on Abbott and Biddle's number 403 packing.

228 Lithium Metal Data. Latest issue of "Foote Prints" discusses uses of lithium in nuclear energy and chemical engineering. Foote Mineral Co.

299 Ethylene Oxide Technical Bulletin. 42-page bulletin gives properties, specifications, uses, and methods of handling. Jefferson Chemical Co.

230 Valve Lubricant Selection Data. Rockwell Manufacturing Co. offers comprehensive bulletin on "Lubricants for Rockwell—Nordstrom Valves." Selection data on about 80 new lubricants.

231 Epoxy Fatty Acid Ester Plasticizers. Methods of preparation and individual properties described in new bulletin from Becco Chemical Division, Food Machinery and Chemical Corp.

232 Silicone Rubber Packing Data. Diaphragms, gasketing, sheet packing, oil seals, rings, insulation tape, and rod and valve stem packing. Technical data from Garlock Packing Co.

EQUIPMENT

233 Potentiometer Data Sheet. Complete specifications of the Type K-3 Universal (Guarded) Potentiometer available from Leeds & Northrup Co.

234 "Servomation" Building Blocks. Enables engineers to understand servo system parameters & their influence on the functioning of even the most complex loops. Catalog from Servo Corporation of America.

235 Corrosion-Resistant Centrifugal Blower. Industrial Plastic Fabricators, Inc., announce availability of new 40-in. dia. PVC blower, Model No. CB-40M, with capacity of 15,000 cu.ft./min. Bulletin.

236 Multi-Station Pirani Vacuum Gauge. A one-to-four station Pirani vacuum gauge with a range from 1 to 2,000 microns Hg is now available from Consolidated Electrodynamics Corp. Data sheet.

237 Booklet on Stainless Castings. 28-page booklet gives detailed information on corrosion- & heat-resisting stainless steel castings. Also physical properties & chemical compositions of stainless steels used in casting. Allegheny Ludlum Steel Corp.

238 Thermometer and Hydrometer Booklet. Complete listing of ASTM general and specific purpose thermometers and hydrometers. Central Scientific Co.

239 Remote-Reading Gages. Available with indicating scale inclined up or down for maximum visibility. Data sheet from Jerguson Gage and Valve Co.

240 Refractometer Data. New bulletin from Phoenix Precision Instrument Co. lists applications, sensitivities, ranges, and other important engineering data on design and use of refractometers in chemical, petroleum, pharmaceutical, and food processing fields.

241 Polyethylene Floats to Cut Evaporation Losses. Agile Mini-Vaps, expanded polyethylene floats which cut evaporation loss of open liquids as much as 75% described in catalog sheet from American Agile Corp. Recommended for fermentation tanks, solvent tanks, etc.

242 Steel Tube Fittings Catalog. Engineering data on Weatherhead 7,000 Series and 8,000 Series Ermeto hydraulic flareless tube fittings and Weatherhead "Flare-Twin" S.A.E. 37° Flare (J.I.C.) hydraulic tube fittings. The Weatherhead Co.

243 Measuring and Control Equipment Catalog. Bulletin 005 lists all major Simplex equipment—controllers, gauges, manometers, recorders, meters, valves, Venturi tubes, etc. Simplex Valve & Meter Co.

249 Controlled-Capacity Pumps. Catalog on Series HP controlled-capacity pumps for pressures to 35,000 lb./sq. in. and capacities to 2,000 gal./hr. Extreme ruggedness with ample safety factor. Philadelphia Pump & Machinery Co.

(Continued on page 70)

DEVELOPMENTS OF THE MONTH (*Cont.*)

281 Continuous Volumetric Feeder. Omega Rotodip Liquid Feeder is a wide-range, precision, corrosion-resistant feeder specially designed to handle dilute or concentrated acids, alkalies, or slurries.

The unit consists of a tank in which the liquid level is maintained by a float valve or overflow weir, a dipper wheel for transferring the liquid over a baffle into a discharge section, a variable speed drive with controls for adjusting the speed of the dipper wheel, and a totalizer to register the dipper revolutions.

Omega Machine Co., division of B-I-F Industries, offers bulletin with line drawing of a typical process installation, dimensional drawings.

(Continued on page 70)

EQUIPMENT (*Cont.*)

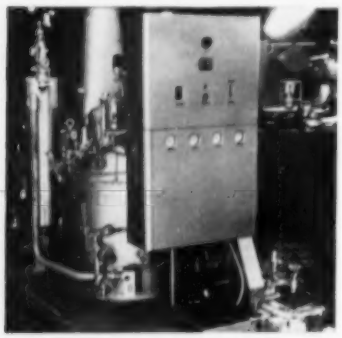
245 Report on Impervious Graphite Equipment Costs. To aid in cost estimation & selection of impervious graphite processing equipment. All standard models listed. Chart of chemical resistances. Falls Industries.

246 Canned Pumps. Seal-less Chempump available at lower cost than ordinary centrifugals. Leakfree operation, no lubrication, simplified maintenance. Technical data from Chempump Corp.

DEVELOPMENTS OF THE MONTH (*Cont.*)

282 Package Steam Generator. The Vapor Modulatic steam generator Model 4615, rated at 60 BHP, produces 400 to 1,750 pounds of steam per hour from 60 degree feed water at 75 to 300 pounds steam pressure.

The unit can develop 200 pounds pressure in two minutes from cold water. Automatic controls cause the steam generator to cycle on and off and change the volume of steam produced to meet changing demand without manual adjustment. A specially-designed servo-water-bypass-control carefully meters the fuel,



feed water and combustion air, permitting operation at about 80% efficiency at all output levels. Working steam pressure may be changed from 75 to 300 lb./sq. in. by turning one control.

Overall dimensions of the 4615 steam generator are 84" long, 48" wide, and 70" high. Each unit is a complete package including 3 HP electric motor, blower, feed water pump, steam separator, fuel pump, and control panel.

Complete engineering details available from Vapor Heating Corp.

(Continued on page 74)

247 Coating & Degreasing Unit. Package vacuum system for coating with vaporized metals, degassing liquids, crystal pulling and growing, etc. Data sheet from Rochester Division, Consolidated Electrodynamics Corp.

248 Forged Steel Valve Data. Material specifications, pressure & temperature ratings, working pressures, dimensions, applications for line of forged steel gate and needle valves. Bulletin from American Chain & Cable Co.

249 Flue Gas Monitoring System. Employs analysis of O_2 content as measure of excess air, automatically adjusts fuel-air ratio to maintain optimum combustion. Leeds & Northrup Co. Technical data.

250 Screw Conveyor Data Book. Capacity charts, horsepower requirements, maximum speeds, design characteristics of all types of screw conveyors. 64-page bulletin from Industrial Division, Continental Gin Co.

251 Self-Powered Feeder. To control the feed of dry, free flowing materials at rates from 200 to 2,000 pounds per minute. Available with automatic shut-off. Engineering data from Wallace & Tiernan, Inc.

252 Safety-Type Temperature Regulator. No. 997 temperature regulator will close automatically to prevent overheating and possible damage to products in process. In sizes from ¼ in. to 2 in. Robertshaw-Fulton Controls Co. Technical data.

253 Motor Selector. Speed-frequency relationship, NEMA design classes, torque characteristics, NEMA current and torque values, frame selection tables, dimension charts. Two-page glossary of terminology. Reliance Electric & Engineering Co.

254 Pressure-Operated Propellant Valves. Can handle liquid oxygen, JP-4, JP-5, red fuming nitric acid, white fuming nitric acid, nitrogen, aniline, propyl nitrate, hydrogen peroxide. Brochure with line sizes, pressures, temperatures, weights. Hydromatics, Inc.

255 Automatic Vapor-Phase Chromatograph. Uses elution method of vapor-phase chromatography. Designed for use in hazardous areas, control unit may be 500 feet way. Engineering details from Consolidated Electrodynamics Corp.

256 Meter Selection Data. 16-page bulletin on complete line of oscillating piston meters. Many tables & charts. Rockwell Manufacturing Co.

257 Rota-Cone Vacuum Dryer. Designed for gentle, efficient, dustless drying of large variety of products. Technical data from Paul O. Abbe, Inc.

258 Seven-way Selector Valve. Multi-port rotary selector valve brings 7 different pipe lines to a central source, eliminates complicated & expensive manifold systems. Bulletin from Win-Well Manufacturing Co.

259 Angular Mixer. Agitator rotates on its angular axis while bach-can & its contents rotate on turntable. Also roller & colloid mills & other power equipment. Technical data from Troy Engine & Machine Co.

260 Instrument Bulletin. Gas pressure manometers, oil flow graduates, sling psychrometers, air velocity meters, filter gauges, recording thermometers, etc. General Scientific Equipment Co.

261 Teflon-lined Steel Pipe. For temperatures as high as 350°F. Standard flange strengths at 125-lb., 250-lb. and 300-lb. In 1-in. 1½-in., 2-in., and 4-in. sizes and 2-ft., 5-ft., and 10-ft. sections. Bulletin from Haveg Industries.

262 Adapter Fittings Catalog. Straight thread plugs and adapters, O-rings for straight thread fittings, and steel and brass pipe fittings. Parker Appliance Co.

263 Nuclear Reactor Bulletins. Foster Wheeler Corp. offers two bulletins, one describing the operation of an aqueous homogeneous power plant, the other covering tank-type research facilities.

264 Mixing Equipment Data. Triple-Action Mixer, Twin-rotor Mixer, Uni-blend mixer, Porta-blend Mixer. Individual bulletins & consulting services offered. Strong-Scott Mfg. Co.

265 Cooling Tower Engineering Data. Bulletin on "Lo-Line" cooling towers made by J. F. Pritchard Co. Mechanical features, cross-sections, dimensions and general arrangement.

266 Phosphate & Phosphoric Acid Plants. Detailed description of plants offered by the Fluor Corp. under license from St. Gobain of France.

267 Automatic Control Catalog. Specifications & engineering data on more than 100 separate control items. Mercoid Corp.

268 Centrifugal Pump Data. Dean Brothers Pumps, Inc. offers data on new line of pumps with capacities up to 600 gal./min. and total dynamic head to 275 ft. Temperatures from minus 40°F. to plus 250°F.

269 Research Reactor Details. Specific uses, design characteristics, safety features & experimental facilities of the General Electric swimming pool, heavy water, & nuclear test reactors.

270 Liquid Processing Equipment Catalog. 40-page catalog describing entire line of stainless steel filters, mixers, tanks, & pumps. Alsop Engineering Corp.

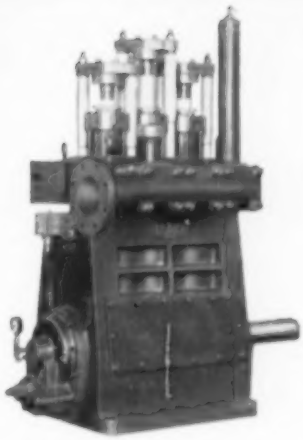
271 Heat Recovery for Pulp & Paper Mills. Booklet describes advantages of direct contact condensers and indirect surface condensers for heat recovery from batch digesters & continuous digester systems. Swenson Evaporator Co.

"It'll pay us to replace it with an ALDRICH PUMP!"

Downtime, due to pump failure, is always a costly item. It takes the reliability and freedom from maintenance found in an Aldrich Pump to assure maximum dependability in overcoming the problems of corrosion, abrasion, high viscosity and high pressures. The tougher the job . . . the more important it becomes to take advantage of our wide experience in building pumps for the chemical industry.

On the less critical jobs, too . . . it makes sense to call Aldrich. The simplicity of the Aldrich Direct Flow design, with fluid-end sectionalization, offers substantial economies in both operation and maintenance. Fluid-end designs are available in aluminum bronze, stainless steel, Hastelloy and titanium.

A copy of our new condensed catalog showing the line of Aldrich Pumps, is yours for the asking. Write today for Data Sheet 100. The Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.



Aldrich Direct Flow Pumps are especially well suited to chemical service. The complete Aldrich line includes Triplex, Quintuplex, Septuplex and Nonuplex Pumps, 25 to 2400 hp.

THE ALDRICH PUMP COMPANY

PRODUCTS ADVERTISED IN THIS ISSUE (*Cont.*)

60L Thorium & Rare Earth Production. Davison Chemical Company's Curtis Bay plant is now processing monazite sand into thorium & rare earths materials for atomic applications.

61A High Pressure Acetylene Chemicals Plant. Plant built by the Lummus Co. for General Aniline at Calvert City, Ky. is first of its type in U. S.

62A Heat Exchangers. Service-proved design, guaranteed job-ratings, fabrication, technical service. General catalog from Efco Heat Transfer Equipment.

67A Heat Transfer Equipment. Every P-K pressure vessel is thermally and physically correct in every way. Patterson Kelley.

69A Scientific Books. John Wiley & Sons are publishers of distinguished books in all areas of pure & applied science.

71A Pump Catalog. New condensed catalog showing the complete line of pumps made by the Aldrich Pump Co.

73A Processing Equipment Fabrication. Skilled craftmanship in all types of steel & alloys. Graver Tank & Manufacturing Co.

75A Stainless Steel Gyratory Screen. Allis-Chalmers gyratory screen gives up to 35 sq. ft. screening area in 16 sq. ft. of floor space.

76A Diaphragm Control Valves. Catalog from Black, Sivalls & Bryson, Inc. gives details of Super "70" Series diaphragm control valves.

77A Urea Plant Design & Construction. Foster Wheeler offers the Pechiney process for the manufacture of urea.

78L Mist Eliminators. "Schuylernit" mist eliminators stop costly liquid loss, improve product quality. Schuyler Manufacturing Corp.

81A Dehydrator. The Sharples "Super-D-Hydrator" produces high purity crystals of very low moisture content at capacities up to 8 tons per hour. Bulletin. The Sharples Corp.

83A Compressors. Cooper-Bessemer M-Line compressors can be furnished with non-lubricated compressor cylinders.

84A Lithium Metal. Lithium Corp. of America can furnish lithium metal by the gram or ton for your processing requirements.

87A Stainless Steel Fabrication. Process equipment in stainless steel and other special alloys. Consulting services. Sun Shipbuilding & Dry Dock Co.

88L Radiation Shielding Windows. New bulletin from Corning Glass Works gives characteristics & applications.

89A Corrosion-Resistant Pumps. Series H Durcopumps available in Durimet 20, 300-series stainless steels, & 11 other standard alloys. Details from Duriron Co.

91A Crystallizers. Designed & engineered to meet specific plant requirements, Conkey crystallizers are made by Chicago Bridge & Iron Co. Technical data.

92L Viscosity Data. More than 300 technical articles and viscosity measurements on 200 materials available from Brookfield Engineering Laboratories, Inc.

93A Process Tubing. Over 63 analyses, including stainless, carbon & alloy steels, nickel & nickel alloys, beryllium, copper, titanium, & zirconium. Bulletin from Superior Tube.

94L Gravimetric Feeders. "Weigh-Flow" Gravimetric Feeders, made by Syntron Co., are built for long, trouble-free service.

95A Plant-Size Reactors. Most advanced design and finest materials available. Bulletin from Autoclave Engineers.

96TL Scale Feeders. Merchen Scale Feeders give accurate continuous blending over a wide feed range. Wallace & Tiernan, Inc. Bulletin.

96BL Precise Low-pressure Gauges. From 0-10 in. water (min.) to 0-30 in. mercury (max.). Bulletin from Wallace & Tiernan, Inc.

97A Temperature Instruments. Complete engineering specifications on Fischer & Porter Co. temperature instruments.

100TL Atomic Energy Instrumentation. Radioactivity instrumentation catalog from Baird-Atomic, Inc.

100BL Reprocessing Service. Truland Chemical Co. specializes in economical upgrading and disposal of solvent mixtures and organic by-products. Consultation on request.

101A Standardized Heat Exchangers. Standardization saves on delivery time and on installation and maintenance costs. Bulletin. Whitlock Manufacturing Co.

102L High Alloy Castings. Experienced help in the solution of difficult corrosion-temperature-strength problems. Duraloy Co.

103A Filteraid Data. Complete information on the seven grades of Dicalite filteraids. Dicalite Division, Great Lakes Carbon Co.

104L Employment Opportunities in Nuclear Field. Physicists, mathematicians, chemical and mechanical engineers wanted. Walter Kidde Nuclear Laboratories, Inc.

105A Dry-Batch Blenders. Sturtevant Dry-Batch blenders speed up production and shorten shut-downs. Sturtevant Mill Co.

106L Filtration Analysis Report. E-D filter paper makes excellent cover for cloth or other filter media. Eaton-Dikeman Co.

107A Heating or Cooling Systems. Beth-Tec standard design systems allow process heating & cooling at 650° to 1,000°F. without pressure. Bethlehem Foundry & Machine Co.

108L Filter Press Catalog. Charts, tables, diagrams to aid operation, maintenance, & selection of filtration equipment. D. R. Sperry & Co.

109A Pressure-Reducing Valve. Bulletin from the Leslie Co. describes new, diaphragm-operated pressure reducing valve.

111A Magnesia Insulation. Johns-Manville 85% magnesia provides high insulating value, easy application, long life, low cost. Details on request.

112L Spray Nozzle Catalog. Applications, sizes, capacities, spray patterns, metals, selection tables. Binks Manufacturing Co.

112R Bolt Tensioner. Controls tightening of bolts without torque. Descriptive folder from Biach Industries.

113R Package Liquid Coolers. Flooded refrigeration principle is effective for handling viscous or slurry-type liquids. Doyle & Roth Manufacturing Co.

114L Small-Diameter Stainless Tubing. Unsurpassed against corrosion, heat, shock, stress, and vibration. Stainless Steel Products Div., J. Bishop & Co. Platinum Works.

115R Strainers. Technical date on many types of industrial strainers. Elliot Co.

116L Flexible Metal Hose. Available in bronze, carbon steel, and Monel with standard or special fittings. Packless Metal Hose, Inc.

117R Precision Aluminum Fabrication. Data sheets and prices for standard or custom-built aluminum equipment. Washington Aluminum Co.

118L Water Chillers. Croll-Reynolds steam-jet Chill-Vactor system can utilize low pressure or waste steam economically.

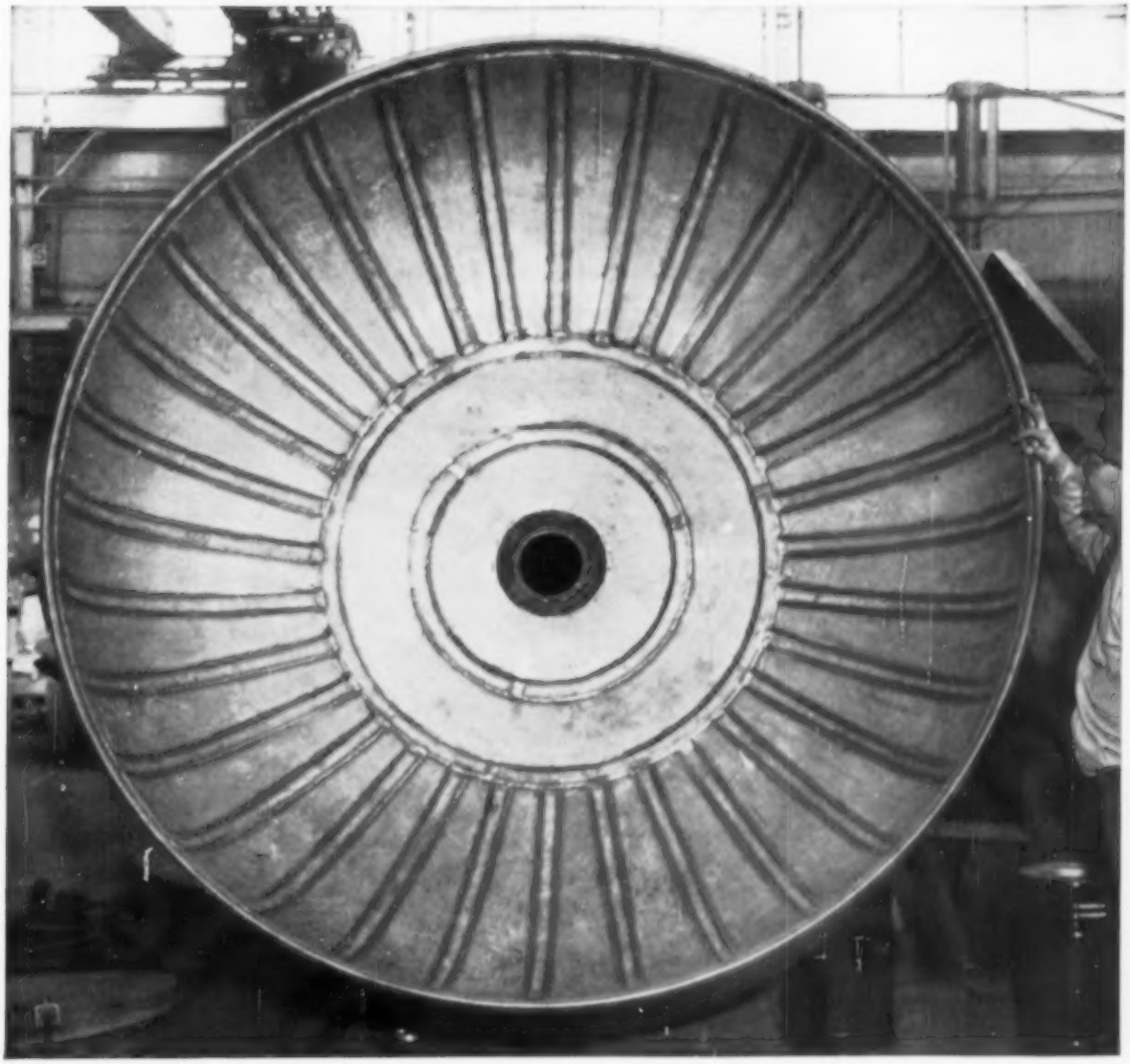
119R Corrosion Protection. Cements, linings, protective coatings, rigid plastic structures. Complete bulletin from Atlas Mineral Products Co.

120L Stainless Steel Tubing. Tube Methods, Inc. specializes in small-diameter stainless steel and special alloy tubing.

120R Liquid Scintillation Spectrometer. Tri-Carb spectrometer is invaluable in industrial applications of radioisotopes. Packard Instrument Co.

121TR Rotary Mechanical Seal. Made to meet specific needs in selected alloys, carbons and ceramics. Bulletin from Durametallic Corp.

(Continued on page 74)



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PRODUCTS ADVERTISED IN THIS ISSUE (*Cont.*)

121BR Rotary Presses. Capacities 65 to over 5,000 tablets/min. Also mixers, granulators, ovens. Arthur Colton Co.

123A Silicon Carbide Refractories. Carbofrax refractories, product of the Carborundum Co., are ideal for mufflers, radiant tubes, retorts, etc. Technical data.

124L Plastic Tanks. Haveg storage tanks, reactors, columns, towers, filters in every type and size in wide range of Haveg grades. Data from Haveg Industries, Inc.

125TL Steam-Jacketed Gear Pumps. SK steam jacketed herringbone gear pumps can handle viscous materials—heavy fuel oils, asphalt, etc. Bulletin. Schutte and Koerting Co.

125BL Ribbon-Type Mixers. For blending slurries, powders, pastes. Details from Cincinnati Hildebrand Co.

sample of Antifoam B will be sent by Dow Corning Corp.

128R pH & Chlorine Control Handbook. Theory and application of pH control. W. A. Taylor & Co.

129R Gear Pumps. Positive displacement, pulseless flow, quiet operation. Bulletin on Gearex Pumps, product of Sier-Bath Gear & Pump Co.

130TL Spray Nozzle Data. Catalog with engineering data on design and performance. Spraying Systems Co.

130BL Portable Filters. Detailed information on portable filters for small batch lots. Ertel Engineering Corp.

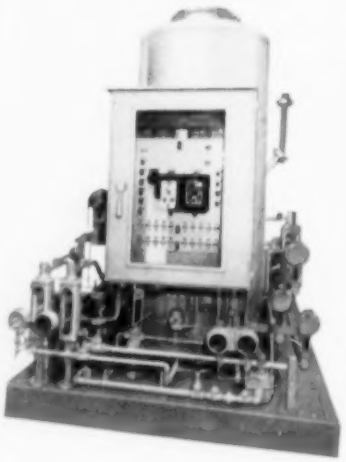
131TR Ceramic-Insulated Thermocouples. "Ceramo" construction ceramic insulation, metal sheathing, provides longer thermocouple life. Bulletin. Thermo Electric Co.

DEVELOPMENTS OF THE MONTH (*Cont.*)

283 Fully-automatic Mixed-Bed IonXchanger. Package units, completely preassembled and ready for connection to water supply, are available from Illinois Water Treatment Co.

The mixed-bed principle of ion exchange provides water that is free of silica and all ionizable solids with purity meter readings of over 1,000,000 ohms per cubic centimeter.

The unit consists of a regular mixed-bed column or tank, with associated external and internal piping, mounted on a heavy welded steel base. Automatic operation is provided by motor-operated valves, controlled by a conductivity meter and program timer to govern regeneration at proper intervals. Vessels and piping for the necessary regenerants are also included. All engineering details available from manufacturer. Circle number 283 on Data Post Card.



125TR Air Filter Catalog. "Airpure" filters give 99.95% or higher efficiency on 0.3 microns and smaller size particles. Flanders Mill, Inc.

125BR Refrigerating and Heating Coils. Fin type or pipe coils for any industrial application. Rempe Co.

126TL Heat Exchange & Process Equipment. All types of process equipment for the chemical processing industries. General bulletin. Manning & Lewis Engineering Co.

126BL Waste Disposal Service. Sea disposal for radioactive materials, poisonous gases, toxic materials, etc. Crossroads Marine Disposal Corp.

127R Venting Manual. Operating features of Protectoseal line of storage tank safety equipment. Protectoseal Co.

128L Silicone Defoamer Sample. Free

131BR Chemical Processing Equipment. Edw. Renneburg & Sons Co. design and manufacture a complete line of pilot plant equipment.

132TL Micro-Microammeter. For the accurate measurement of extremely low currents. Bulletin describes the Beckman Process Instruments' Model V.

132BL Geiger Counter Gases. Compressed Gas Catalog describes 72 compressed gases, gas mixtures, pressure regulators, etc. Matheson Co.

133R High-Speed Vacuum Pump Data. Single-stage or compound units to meet any capacity requirement. Roots-Connersville Blower.

134TL Crusher Catalog. Crushers for any processing application. Bauer Bros. Co.

134BL Pump Catalog. Complete range of sizes, horizontal and vertical shaft types. Nagle Pumps, Inc.

O CIRCLE *your Data Service requests on the handy postcard on page 64 to*

▶ GET *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes, equipment.*

135R Flowmeters. The Pottermeter assures reliable high-pressure and temperature operation with high repeatable accuracy. Potter Aeronautical Corp. Bulletin.

136B Steel Plate Fabrication. Tanks, digesters, pressure vessels to the most exacting specifications. Posey Iron Works, Inc.

137R Heating and Cooling Coils. "Aerofin" smooth-fin coils offer greater heat transfer and lower airway resistance. Bulletin from Aerofin Corp.

138L Alloy Fabrication. Misco Fabricators, Inc. specialize in heat and corrosion-resistant process equipment.

138BR Counters for Nuclear Applications. Special and standard counters to meet individual research needs. Catalog from N. Wood Counter Laboratory.

139TR Granular Drying Agent. Florite desiccant has longer service life, gives low dew point depression. Floridin Co.

152TL Thermo-Panel Coil. Bulletins with technical data, design, and price information on Dean Thermo-Panel Coil. Dean Products, Inc.

152BL Nuclear Engineering Services. Reactor physics, radiation chemistry, employment opportunities. Astra.

153BL Indicating Pyrometers. Twenty-one ranges from minus 400° to plus 3,000°F. 40-page catalog. Assembly Products, Inc.

153TR Pump Catalog. Sigmamotor pumps handle liquids, gases, slurries without corrosion or contamination. Catalog. Sigmamotor, Inc.

153BR Precision Mixer. 100 to 8,000 lbs. per batch. Data from H. C. Davis Sons' Mill Machinery Co.

IBC Multiplier Phototubes. Wide selection of sizes and electrical characteristics for every photoelectronic need. Allen B. Du Mont Laboratories, Inc.

OBC Chemical Process Mixing Equipment. Expert consulting help available from Mixing Equipment Co. on selection of proper equipment.

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NEW in Design ...Performance ...Economy

Stainless Steel Construction makes cleaning easy... is corrosion resistant.

Large Screening Capacity. Self-contained unit provides as much as 35 square feet of screening area in 16 square feet of floor space. Gyratory action exposes product to all of screen cloth.

Wide Sizing Range permits handling of product sizes from 4 to 200 mesh.

Extra Cooling Surface of rib-type motor eliminates insulation burnouts under normal operating conditions.

Simplified Dismantling. Vertically locked deck arrangement eliminates need for enclosure. External tie rods facilitate fast removal of decks.

No hard-to-clean Nooks and Corners.

Dust-Tight — wide variety of installation-proved materials available for compression-type seals.

Two, Three, Four Separations . . . one outlet for each different size product. Collars and adjustable changes provide for quick attachment of flexible outlet tubes.

Full Freedom of Gyratory Motion made possible by universal-type stabilizers. No lubrication needed.

Low Power Requirements. A 1-hp motor drives unit of three or four decks.

Quiet, Vibrationless Operation assured by dynamically balanced mechanism.

Product Quality Protected. Gentle motion minimizes disintegration of foreign particles.

Secure, Vibrationless Foundation provided by sturdy, all-welded steel base.

You Get **MORE** When You Specify ALLIS-CHALMERS

Top efficiency in screening . . . maximum capacity . . . profit-insuring quality control . . . quick 'n' easy sanitation . . . simplified maintenance . . . economical operation — all these important advantages are yours when you specify Allis-Chalmers.

Your Allis-Chalmers representative will be glad to tell you more about this newest and finest of gyratory screens. Call him. Or write for descriptive Bulletin 07B8446. Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

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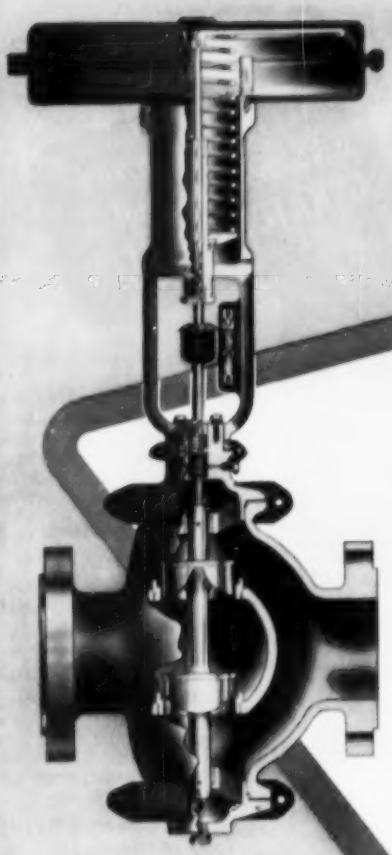
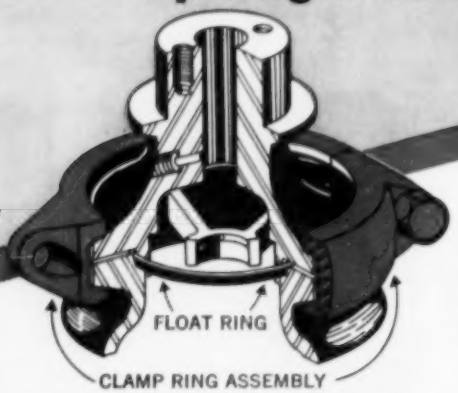
A-5074

New Clamp Ring···Float Ring Seal*

On BS&B's *Super* 70 *series*

Diaphragm Control Valves





...Makes Other Valve Closures Obsolete!

The BS&B Super "70" Series Diaphragm Control Valves offer a thoroughly proven concept of pressure sealing, known as the clamp ring — float ring seal, for top and bottom closures.

Tightening of the heavy forged steel clamp ring seals the nickel plated, soft steel float ring into a precision machined, wedge-shaped groove formed by the valve body and the closure plate. Float rings are available in other materials compatible with alloy or stainless steel valve bodies.

Under pressure, the float ring is wedged tighter into its annular groove — thus increasing the sealing force. The higher the internal pressure, the tighter the seal!

This actuation under pressure also creates automatic compensation for thermal expansion under fluctuating temperatures. The seal is maintained under vacuum because initial tightening of clamp ring provides sufficient sealing force to hold a vacuum differential of up to 15 psi. Valves may be disassembled as often as required without damage to the clamp ring — float ring seal.

While a new BS&B exclusive feature in the diaphragm valve field, the float ring seal concept has also been most successfully used over the past several years by other leading manufacturers of high pressure equipment.

* Patented

Why Clamp Rings Are Used On Super "70" Series Valves

The equivalent bolting area of the clamp rings used on Super "70" Series Valves is greater than that of a similarly rated ASA flange — yet is lighter in weight and more trim in appearance. Clamp rings make the valve easier to disassemble for servicing and cleaning because only two bolts must be removed, and permit the valve yoke to be oriented to any convenient position.

For more information on the all-new BS&B Super "70" Series Diaphragm Control Valves, ask your BS&B Sales Engineer — or write for Catalog 70-11.

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Two of the world's largest urea plants using the Pechiney process have been designed and constructed by Foster Wheeler. They have a combined capacity of 400 Tons per day of urea prills.

The design of these plants followed the most advanced technology aimed at producing a high-quality product at minimum cost.

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For further information, write to *Foster Wheeler Corporation, 165 Broadway, New York 6, N. Y.*

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DECLASSIFIED REACTORS

AEC REACTORS (Cont.)

(*Continued from page 60*)

PWR, Pressurized Water Reactor (AEC and Duquesne), Shippingport, Pa.
Reactivity Measurement Facility, MTR canal, National Reactor Testing Station, Idaho.
SNSE, School for Nuclear Science and Engineering (see Argonaut).
SPERT-1, Special Power Excursion Reactor Test-1, National Reactor Testing Station, Idaho.
SPERT-2, Special Power Excursion Reactor Test-2, National Reactor Testing Station, Idaho.
SPERT-3, Special Power Excursion Reactor Test-3, National Reactor Testing Station, Idaho.
SRE, Sodium Reactor Experiment, Santa Susana, California.
SUPO, Super Power Water Boiler, Los Alamos.
TTR, Thermal Test Reactor, Hanford.
TTR, Thermal Test Reactor, Schenectady, N.Y.
WBNS, NAA Water Boiler Neutron Source, Van Nuys, California.
WGR, Water Graphite Reactor Experiment, Hanford.

NON-AEC REACTORS

Aerojet-General Nucleonics, San Ramon, California. (AGN-1 and other reactors of the same type.)
American Machine & Foundry.
Armour Research Foundation, Chicago, Illinois.
Battelle Memorial Institute, Columbus, Ohio.
California, University of (see UCLA).
Chugach Electric Association, Inc., and Nuclear Development Corp. of America, Anchorage, Alaska.
Commonwealth Edison Company (Nuclear Power Group), Dresden, Illinois.
Consolidated Edison Company, Indian Point, New York.
Consumers Public Power District, Beatrice, Nebraska.
Curtiss-Wright Corporation, Quehanna, Pa.
Dow Chemical Company, Midland, Michigan.
Florida, University of, Gainesville, Florida.
Florida Power Corporation, et al, Florida.
Gamma Corporation, Mansfield, Massachusetts.
GE-Pacific Gas & Electric, Pleasanton, Calif.
Holyoke, City of; Holyoke, Massachusetts.
Industrial Research Laboratories, Inc., Plainsboro, New Jersey.
Massachusetts Institute of Technology, Cambridge, Massachusetts.
Michigan, University of; Ann Arbor, Michigan.
National Advisory Committee for Aeronautics, Sandusky, Ohio.
Naval Research Laboratory, Washington, D. C.
North Carolina State, Raleigh, N. C.
Nuclear Power Group (see Commonwealth Edison Company).
Orlando, City of; Orlando, Florida.
Pennsylvania Power & Light Company, Easton, Pennsylvania.
Pennsylvania State University, University Park, Pennsylvania.
Piqua, City of; Piqua, Ohio.
Power Reactor Development Company, Monroe, Michigan.
The Prosperity Company, Coral Gables, Florida.
Rural Cooperative Power Association, Elk River, Minnesota.
Stanford Research Institute, Palo Alto, Calif.
UCLA Medical Reactor, Los Angeles.
Washington, University of; Seattle, Washington.
Washington State College, Pullman, Washington.
Watertown Arsenal, Watertown, Massachusetts.
Westinghouse Testing Reactor, Westmoreland County, Pennsylvania.
Wolverine Electric Cooperative, Hersey, Mich.
Yankee Atomic Electric Company, Rowe, Massachusetts.

Philadelphia's Convention Hall: Site of all events of the 1957 Nuclear Congress and International Atomic Exposition.

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MARCH 11-15, 1957

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TURN PAGE FOR RESUME OF TECHNICAL PROGRAM

2ND NUCLEAR ENGINEERING AND SCIENCE CONFERENCE
March 11-14, 1957

Sponsored and conducted by 20 leading engineering and scientific societies under the coordination of Engineers Joint Council.

More than 150 technical papers will be presented by the nation's leading engineers and scientists during 32 sessions covering such topics as:

- *Reactor Design, Metallurgy, Control, Instrumentation, Shielding and Construction*
- *Reactor Components, Operation, Maintenance; Standardization*
- *Waste Disposal; Water Supply Protection*
- *Natural Resources; Fuel Production and Processing*
- *Thermodynamics and Coolant Systems*
- *Safety; Radiation Protection*
- *Use of Educational Nuclear Reactors*
- *High Intensity Radiation Processing*
- *Fusion*

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2. *Engineers Joint Council*
   29 West 39th Street
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INTERNATIONAL ATOMIC EXPOSITION
March 11-15, 1957

Sponsored by the American Institute of Chemical Engineers with the cooperation of the American Society of Civil Engineers, the American Institute of Mining, Metallurgical and Petroleum Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers.

See the latest equipment, materials, and processes relating to the non-military uses of atomic energy in its various forms on display—many of them for the first time. Virtually all major suppliers or services to the nuclear energy field—from mining equipment and supplies to power distribution, electronics, chemical, metallurgical, mechanical, and many others—will display. Foreign industry and government will also be represented.

In addition to the thousands who registered for the technical sessions at the 1955 Nuclear Congress, over 15,000 registered to view the 165 exhibits—engineers, scientists, executives from industry, purchasing officials, press, educators, technical students, etc. Attendance at the 1957 Congress is expected to be even bigger.

Headquarters for exhibit information is:

International Atomic Exposition
117 South 17th Street
Philadelphia 3, Pennsylvania

5TH ATOMIC ENERGY IN INDUSTRY CONFERENCE
March 14-15, 1957

Sponsored and conducted by the National Industrial Conference Board (460 Park Ave., N.Y. 22)

Reports on current and future economic effects of atomic energy and the way experienced companies are dealing with managerial problems arising from the generation of nuclear power and use of atomic by-products in research and production. The 14 sessions cover such topics as:

- *New markets for new metals and how to realize them*
- *Better product development through radioisotopes, radiation chemistry*
- *Safety, health, insurance, legislation*
- *Status of foreign and domestic atomic energy developments*

5TH HOT LABORATORIES AND EQUIPMENT CONFERENCE
March 14-15, 1957

Sponsored and conducted by the Hot Laboratory Committee

More than 60 technical papers presented by designers and operators of laboratories handling radioactive materials. Six sessions cover new developments in hot laboratories and cells, remote handling equipment, and hot cell operation.

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Program details for Second E.J.C.

NUCLEAR CONGRESS

The efforts of more than 20 professional societies and trade associations have been combined to form a Nuclear Congress program of exceptional breadth of interest to chemical engineers. All technical sessions are listed. Fuel Cycle sessions sponsored by A.I.Ch.E.'s Nuclear Engineering Division are specially designated. Through pre-publication in this issue of *CEP* of somewhat condensed versions of eleven papers of the Fuel Cycle sessions, the reader will be able better to prepare himself for following the full presentations, and for discussion opportunities. Preprints of all papers are available through order forms mailed to society members with the program booklet. Additional copies of preprint order forms may be had from E.J.C. Congress Manager, A.S.M.E., 29 W. 39 St., New York, N. Y.

MON., MARCH 11 (A.M.)

PLANT CONTAINMENT CONCEPTS AND DESIGN: Chairmen: L. R. Gaty, W. C. Siler. **Consolidated Edison Containment System,** H. F. Dobel and D. W. Montgomery, Babcock & Wilcox. **Containment for the EBWR.** Design parameters for containment of gaseous and particulate materials and missiles. L. W. Fromm and A. Heineman, Argonne. **Power Reactor Containment Vessels,** A. J. Raymo, G. E.

A.I.Ch.E. FUEL CYCLE SESSION 1, FUEL PRODUCTION: Co-Chairmen: F. L. Cuthberth, F. Culler. **Pilot Plant Studies on Nonaqueous Extractive Methods for Western Uranium Ores.** Operating data and conditions for 90 to 95% uranium extraction. D. D. Foley, W. A. Meeley and R. B. Filbert, Battelle. **Refining of Uranium Ore Concentrates.** Solvent extraction of slurries. D. S. Arnold and B. G. Ryle, National Lead. **The Use of a Fluidized Bed Process for the Production of Green Salt (UF).** Conversion of uranium trioxide to uranium tetrafluoride. N. Levitz, E. J. Petkus, H. M. Katz and A. A. Jonke, Argonne. **Uranium Recovery at the Oak Ridge Gaseous Diffusion Plant.** Details of facility for recovering uranium from aqueous solutions. R. J. Clouse, J. Dykstra and B. H. Thompson, Union Carbide Nuclear. **The Uranyl Ammonium Phosphate Process for Recovery of Uranium from MgF_2 Slag Scrap.** Thousands of tons of scrap are to be reprocessed. Here is one process which may be used. E. R. Johnson, E. O. Rutenkroger, A. B. Kreuzmann and B. C. Doumas, National Lead. **Methods for Production of Thorium Metal.** A demonstrated process plus processes currently in development stage. O. C. Dean, Oak Ridge.

PROTECTION OF WATER SUPPLIES: Chairmen: F. S. Friel, S. S. Baxter. **Radioactive Tracers in the Field of Sanitary Engineering.** Time of passage in streams and pilot plant facilities, holding time in short-time high-temperature equipment. C. P. Straub and R. G. Hagee, Taft Sanitary Eng. Center. **Stream Surveys for Radioactive Waste Control.** Organization of surveys. E. C. Tsivoglou and W. H. Ingram, Taft Sanitary Engrg. Center, and E. D. Harward, AEC. **Radiochemical Procedures for the Identifications of the More Hazardous Nuclides.** Determination of Ra, Co, Sr, Ba, Cs, etc. B. Kahn, ORNL, and A. Goldin, Taft Sanitary Engrg. Center.

EDUCATIONAL USE OF REACTORS: Chairmen: C. F. Bonilla, W. W. Miller. **The Water Boiler as an Instructional Tool,** C. K. Beck, AEC. **Educational Uses of the Small 5-Watt Laboratory Reactor.** Small, inexpensive source. J. W. Flora, Atomics Internat. **The Portable Polyethylene-Moderated Training and Research Reactor (AGN-201).** Small, inexpensive source. A. T. Biehl and R. A. Fayram, Aerojet-General Nucleonics. **The Thermal Test Reactor.** Heterogeneous, oil or water cooled, graphite-moderated. H. B. Stewart, G. B. Gavin and R. E. Slovacek, Knolls. **Reactor Experiments in ORSORT.** H. Pomerance, Orsort. **Reactor Experiments at ISNSE—The Argonaut (part 1).** Small, inexpensive source. R. H. Armstrong, C. N. Kelber, D. H. Lennox and B. I. Spinrad, Argonne. **Reactor Experiments at ISNSE—Subcritical Assemblies (part 2)** H. Bryant, Argonne. **Educational Uses of the "Pickle-Barrel."** Small, inexpensive source. R. M. Stephenson and H. Ager-Hanssen, N. Y. U.

MON., MARCH 11 (P.M.)

A.I.Ch.E. FUEL CYCLE SESSION 2, FUEL CYCLE INTERRELATIONSHIPS: Co-Chairmen: E. B. Gunyou, J. C. Robinson. **Reactor Complex Interdependence Resulting from Fuel Recycle.** Comparison of decontamination routes. W. A. Rodger and S. Lawroski, Argonne. **Reactor Design and the Fuel Cycle.** High power density and long life with continuous operation. R. B. Spooner, Koppers. **Fuel Element Fabrication.** Uranium elements. A. R. Matheson, Metals & Controls Corp. **The Fuel Cycle from the Standpoint of the Fuel Processor.** C. E. Stevenson, Phillips Petroleum. **Fuel Cycles in Single-Region Thermal Reactors.** Procedure for calculation of interrelationships between reactor & fuel reprocessing plant. T. H. Pigford and M. Benedict, M.I.T.

WASTE DISPOSAL I: Chairmen: J. C. Geyer, J. A. Lieberman. **Disposal of Radioactive Wastes.** Report of National Academy of Sciences committee. A. Wolman, Johns Hopkins. **Over-all Geologic Approach to Disposal.** Underground beds may take large volumes of waste. H. H. Hess, Princeton University. **Disposal of Radioactive Wastes in Reverse Wells.** Surface dispersal and sub-surface injection systems. W. J. Kaufman, Univ. of Calif. **Problems Facing State Agencies in Handling Treatment and Disposal of Radioactive Wastes.** E. F. Eldrige, Wash. State Pollution Control, E. C. Jensen, Wash. State Dept. of Health; C. M. Everts, Jr., Oregon State Board of Health and H. C. Clare, U. S. Public Health Service.

(Continued on page 82)

The accompanying communication has been received from the co-chairman of Fuel Cycle Session 4, Aqueous Reprocessing, being an interpretation of the contents of the session. It is presented herewith to aid the reader in realizing the full potential intended by those who planned and organized this session. Abstracts of Fuel Cycle Sessions 1, 2, and 5 were presented in the January issue of C.E.P.

Correction: Last month CEP published a resume of Fuel Cycle Session 2 by E. B. Gunyou of Koppers Co. He was incorrectly indicated as connected with Vitro.

A.I.Ch.E. Fuel Cycle Program, Session 4: Aqueous Reprocessing

By R. B. Richards, G. E.

It is not possible today to formulate exact conclusions regarding the role of aqueous reprocessing in the overall Fuel Cycle. This is perhaps not unique to this particular area of technology since the future of metallurgical reprocessing, fuel element burnout, materials, and heat transfer all enjoy similar degrees of uncertainty.

Much of significance, however, can be said along philosophical lines and certain qualitative conclusions drawn about the future of aqueous reprocessing.

It would require a symposium of prohibitive length to develop the full picture of where reprocessing stands today in technological growth. The most that can be offered in such a limited session will be to touch upon some highlight problems and develop some of the considerations of future development and potential through our discussions of the various papers.

To set the stage for such discussions we should consider the power reactor

(Continued on page 82)

ENGINEERING DEPT.—SUMMARY REPORT

To: T.M.D. Vice Pres., Production

From: R.R.G. Chief Engr., Inorganics

SUBJECT: Test Program—Sharples Super-D-Hydrator, caustic soda production.

MATERAL: Slurry from double effect evaporator taken from second effect underflow at 25% sodium hydroxide concentration.

OBJECTIVE: a. Recovery of sodium chloride crystals with minimum entrained caustic.

b. Reduction of sodium sulphate content of sodium chloride crystals by use of brine rinse.

RESULTS: Production runs were made on a C-27 Super-D-Hydrator under controlled conditions of application of cell liquor, water, and saturated brine rinses.

At a capacity of 4.50 tons of salt per hour, using 0.1 lbs. of rinse water per lb., and 0.7 lbs. of brine per lb. of salt, the salt crystals were discharged at 0.1% NaOH content with less than 0.6% sodium sulphate.

ACTION: The sulphate-laden brine rinse was automatically kept separate from the mother liquor and the valuable alkali-bearing rinse liquor.

Immediate recommendation of the purchase of four C-27 Super-D-Hydrators to meet our existing requirements. This same equipment will handle 20% expansion when our new source of low sulphate salt goes into production.

NUCLEAR CONGRESS PROGRAM

MERCHANT SHIP SAFETY: Chairmen: H. W. Pierce, H. M. Tiedemann. **Development of Safety Standards for Nuclear Propulsion of Merchant Ships.** C. P. Murphy, U. S. Coast Guard, A. R. Gatewood, Amer. Bur. of Shipping. **Some Possible Safety Measures for Nuclear Merchant Ships.** R. H. Fayram, Aerojet-General Nucleonics.

REACTOR OPERATION AND MAINTENANCE: Chairmen: P. N. Ross, R. G. Lorraine. **The Homogeneous Reactor Test Mockup.** Flow Sheet, Fuel Solution Stability, Corrosion, Instrumentation. I. Spiewak, H. L. Falkenberry, Oak Ridge. **Some Operational Problems of the Nuclear Power Plant.** Start-up, Normal Operation, Shut-Down, Refueling, Maintenance, Manpower. R. L. Witzke and A. R. Jones, Westinghouse. **Opportunities for Reducing the Investment and Operating Costs of Utility Size Nuclear Power Plants.** H. R. Hughes, G.E.

TUES., MARCH 12 (A.M.)

A.I.Ch.E. FUEL CYCLE SESSION 3, FUEL MANUFACTURE: Co-Chairmen: F. G. Foote, R. B. Briggs. **Fabrication of Irradiated Reactor Fuels by Semiautomatic Remote Controlled Equipment.** Processes and equipment to refabricate irradiated fuels. A. B. Shuck, Argonne. **High Uranium Alloy Fuel Plate for the Experimental Boiling Water Reactor.** R. E. Macherey and C. H. Bean, Argonne. **Oxide Fuel Elements for Borax-IV.** Ceramic materials as reactor fuels. J. H. Handwerk and R. A. Noland, Argonne. **Preparation and Properties of Aqueous Thorium-Uranium Oxide Slurries.** J. P. McBride, V. D. Allred, C. E. Schilling and E. V. Jones, Oak Ridge.

STANDARDIZATION IN THE NUCLEAR FIELD, (PANEL SESSION): Chairmen: Admirals Kitts, III, G. F. Hussey. **General and Administrative Standards.** W. A. Kitts, III, G.E. **Nuclear Instruments.** N. Anton, Anton Electronic Lab. **Electrical Requirements for Nuclear Reactors and Atomic Systems.** R. C. Sogge, G.E. **Chemical Engineering in the Nuclear Field.** R. P. Genereaux, DuPont. **Reactor Hazards.** H. Wagner, Detroit Edison. **Radiation Protection in the Nuclear Field.** W. A. McAdams, G.E.

WASTE DISPOSAL II: Chairmen: Roy J. Morton, B. A. Poole. **Disposal of Fission Products in Glass.** R. W. Durham, A.E. of Canada. **Geo. Consider. of Waste Disposal—Thermal Considerations.** H. E. Skibitzke, U. S. Geol. Survey. **Atomic Waste Disposal by Injection into Aquifers.** E. Roedder, U. S. Geol. Survey. **Separation of Cesium and Strontium from Calcined Metal Oxides as a Process in Disposal of High Level Wastes.** A. Abriss, J. J. Reilly and E. J. Tuthill, Brookhaven.

PRIMARY COOLANT SYSTEMS: Chairmen: W. H. Jens, J. P. Hartnett. **Engineering Consideration in the Use of an Organic Reactor Coolant.** W. E. Parkins et al, Atomics Internat. **Use of Boiling Water as a Reactor Coolant.** Supercritical pressures suggested to improve efficiency and performance. S. Untermeyer, G.E. **Gas Coolant for Nuclear Reactors.** M. Silverberg, Ford Instrument. **Operational Experience with a UO_2-NaK Slurry in a Loop at 600 C.** H. E. Flotow, R. D. Carlson and B. M. Abraham, Argonne.

TUES., MARCH 12 (P.M.)

PLANT COMPONENTS—SMALL: Chairmen: J. Frank Roberts, L. Koch. **Pumps for Nuclear Power Plants.** Types now in use and requirements for new types planned. A. F. Erwin, Allis Chalmers. **5000 GPM Electromagnetic and Mechanical Pumps for the EBR-II Sodium System.** Curves showing head-capacity, power input, voltage control of flow, and efficiency. O. H. Seim and R. A. Jaross, Argonne. **Use of Clad Piping.** J. H. Proctor, Lukens Steel. **Piping as Applied to Nuclear Energy Applications.** Plastic deformation erection and normal and emergency services, sensitivities of materials. D. B. Rossheim, J. J. Murphy, C. R. Soderberg and H. S. Blumberg, M. W. Kellogg. **On Quality Requirements for Steel Valves for Nuclear Power Plants.** J. J. Kanter, Crane. **60 Cycle Induction Heating of Sodium Systems.** Heating of loops including elbows, flanges, valves. R. A. Jaross, Argonne.

NEW LIMITS AND CODES FOR RADIATION PROTECTION: Chairmen: J. W. Healy, C. M. Paterson. **Changes in Maximum Permissible Exposure Values Recommended in 1956 by the International Commission on Radiological Protection.** K. Z. Morgan, Oak Ridge. **The Impact of the Lowered Radiation Exposure Limits on Radiation Control Problems.** L. S. Taylor, Nat. Bur. of Standards. **Status of Radiation Protection Legislation and Codification.** W. A. McAdams, G.E. **Regulations Controlling the Use of Radioactivity by AEC Licensees.** F. Western, AEC. **Statistics on Radiation Exposures for Use in Labor, Insurance, Economic and Scientific Studies.** W. D. Claus, AEC.

SHIELDING — STRUCTURAL PROTECTION AND CONTROL OF FISSION PRODUCTS: Chairmen: J. G. Terril, Jr., H. L. Bowman. **Control of Radioactive Material at the Pressurized Water Reactor.** J. R. La Pointe, Westinghouse. **Structural Properties of Magnitite Concrete.** J. M. Raphael, Univ. of Calif. **Materials of Biological Shielding.** H. M. Glenn, Oak Ridge.

TUESDAY, MARCH 12, 7:00 p.m.

A.I.Ch.E. Nuclear Engineering Division Dinner. Sheraton Hotel, Pennsylvania Room, 17th Street and Pennsylvania Boulevard, Philadelphia. Ladies Welcome. Price $7.

Speaker: Dr. W. Kenneth Davis, U. S. Atomic Energy Commission.

PLANT COMPONENTS: Structural Features of the Waste Disposal System for the Shippingport Atomic Power Station, Shippingport, Penna. H. T. Evans, Stone & Webster. **The Application of Radioisotopes to the Measurement of Soil Moisture Content and Density.** P. F. Carlton, Corps of Eng. U. S. Army.

A.I.Ch.E. FUEL CYCLE SESSION 4, SPENT FUEL PROCESSING—AQUEOUS: Chairmen: R. B. Richards, D. H. Ahmann. **Head-end Steps in Preparation of Fuels for Aqueous Processing.** J. A. Buckham, Phillips Petroleum. **New Developments in Head-End Methods for Preparation of Fuels for Aqueous Processing.** R. E. Blanco and J. E. Savolainen, Oak Ridge. **Comments on Waste Disposal at Hanford.** A new waste scavenging process. M. J. Steadwell and R. E. Burns, Hanford. **An Ion Exchange Process for the Recovery of Plutonium from Irradiated Fuels.** A. M. Aikin, A.E. of Canada. **Waste Disposal as Related to Chemical Processing.** Problems associated with each of several proposed processing schemes. G. G. Robeck and P. Straub, R. A. Taft Sanitary Eng. Center. **An Electrolytic Recycle for Waste Treatment.** H. W. Alter and D. L. Barney, Knolls. **Nuclear Safety Considerations in Reactor Fuels Processing Plant Design.** N. Ketzlach, Hanford.

WED., MARCH 13 (A.M.)

PLANT COMPONENTS—LARGE: Chairmen: A. N. Anderson, M. C. Beekman. **Boilers for Nuclear Power Plants.** Advantages and disadvantages of boilers for stationary nuclear power plants. J. Cartinhour, Foster Wheeler. **Problems Encountered in the Design of Pressurized Water Reactor Vessels to Meet the Intent of the Boiler Code.** S. L. Lindbeck, Westinghouse and A. D. Halporn, Jr., Combustion Engineering. **Basic Equations for Predicting Performance of a Nuclear Power Plant Pressurizer.** System pressure during changes in reactor power level predicted by transient thermodynamics. T. Glasser, Knolls. **Fuel Handling System for a Fast Breeder Reactor.** Design criteria, special environmental problems, service factors, maintenance. J. E. Seward and C. P. Nash, APDA.

(*Continued on page* 106)

FUEL CYCLE, SESSION 4

(*Continued from page* 80)

cycle as a whole. Most engineers and scientists would agree that all efforts are really being directed toward realization of the low thermal energy cost that the fission reactions appear to offer from their fuel. Approaches have varied widely and opinions have ranged broadly. From the several facts relating to chemical reprocessing emerge:

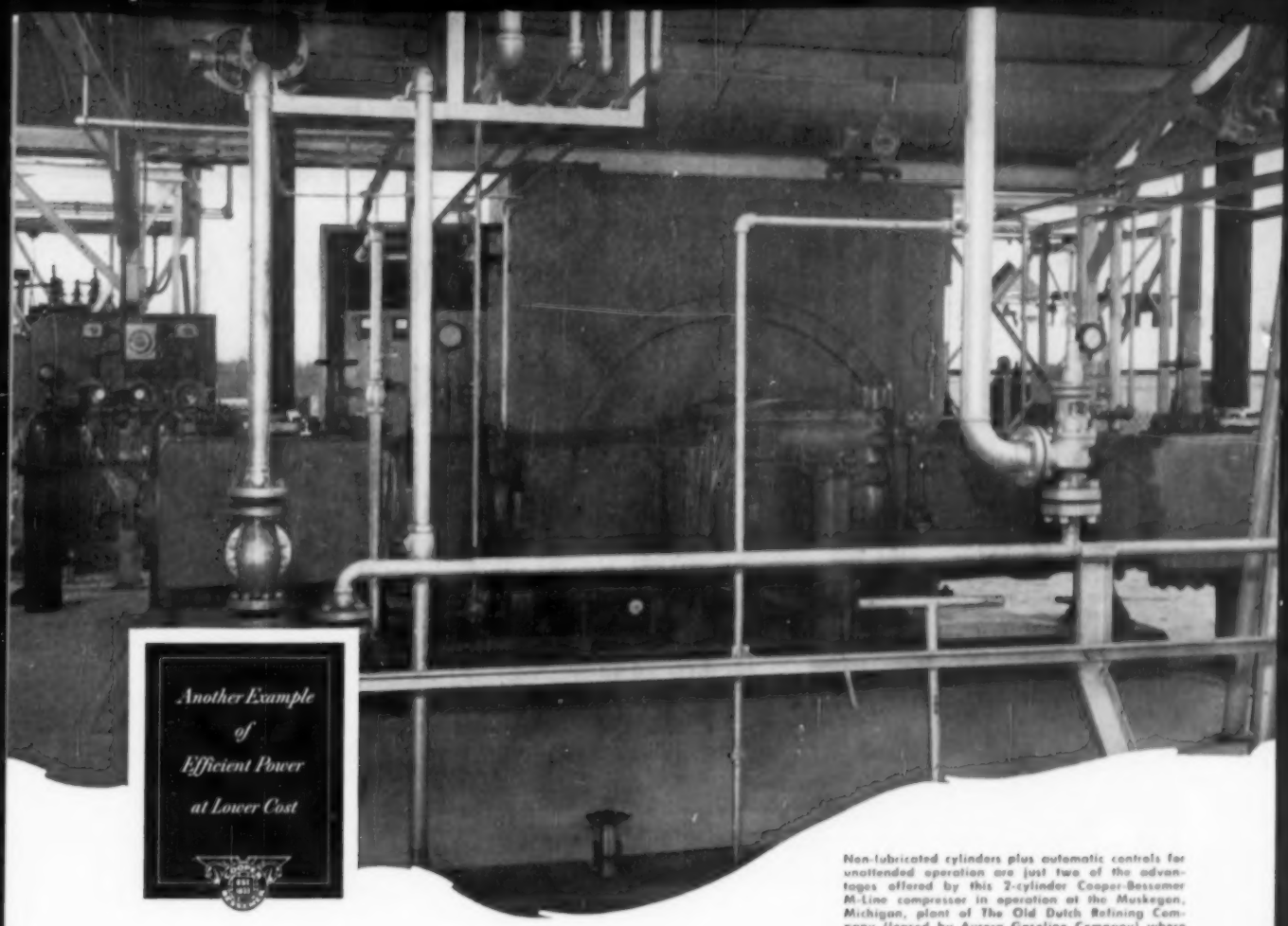
***First*, there have been no technological break-throughs that have eliminated reprocessing from consideration in the overall Fuel Cycle.**

***Second*, the nature of the metallurgical problems associated with a high-burnout fuel element at low cost are such that more workers are concluding that incentives for cheap and effective reprocessing schemes may very well equal the incentives for the cheap fuel element of super integrity.**

There is a school of thought that contends that progress in the development of cheap metallurgical pieces will never reach the fullest economic potential because this approach is in direct opposition to the long-standing rule that nature requires periodic purging and elimination of wastes and poisons for continued functioning. Proponents of this school can point to numerous technological case histories to support their position as well as the usual examples found in nature.

Whether we agree or disagree with this philosophy or accept it with certain practical reservations, there is no doubt that chemical reuse as a step in the power reactor cycle is still in the picture and there are reasons to believe that it may assume an increasing degree of importance as time goes on.

The foregoing are but some of the reasons why we should approach the subject matter of this symposium, and the discussion which follows, with the conviction that this area may become a key one in the future of the atomic energy business.



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ATOMIC EXHIBITORS

ACF Industries, Incorporated, Nuclear Energy Products Division, Washington D. C. (141)
Section drawings of research, material-testing and power reactors.

Acoustica Associates, Inc., Glenwood Landing, L. I., N. Y. (428)
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Aerojet-General Nucleonics, San Ramon, Calif. (270)
Mass produced laboratory reactor

Aeroprojects Incorporated, West Chester, Pa. (304)
Ultrasonic equipment.

Allis-Chalmers Mfg. Co., Milwaukee, Wisconsin (421)
Canned & magnetic pumps.

American Institute of Chemical Engineers, New York, N. Y. (156)
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AMF Atomics, Inc., New York, N. Y. (117, 119, 121)
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Argonne National Laboratory, Lemont, Illinois (448)
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Assembly Products, Inc., Chesterland, Ohio (232)
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Atomic Associates, Inc., Jamaica, N. Y. (426)
Radioactivity measuring instruments. Radioisotopes.

Atomic Energy of Canada Limited, Commercial Products Division, Ottawa, Canada (148)
Radioactive isotopes and equipment for research and industry.

U. S. Atomic Energy Commission, Washington 25, D. C.
Assistance to industry.

The Babcock & Wilcox Company, New York, N. Y. (128, 132)
Nuclear reactors and fuel elements.

Baird-Associates-Atomic Instrument Co., Cambridge, Mass. (424)
Radiation field survey instruments

Battelle Memorial Inst., Columbus, Ohio (345)
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Beckman Instruments, Inc., Berkeley Division, Richmond, California (417)
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Three looseleaf binders of a business service on the atomic industry. Title: Atomic Industry Reporter.

Byron Jackson Division, Borg-Warner Corporation, Los Angeles, Calif. (408)
Pumping equipment for nuclear reactors.

The Carpenter Steel Company, Alloy Tube Division, Union, N. J. (310)
Stainless steel and high alloy tubing and pipe.

Catalytic Construction Co., Philadelphia, Penna. (328, 332)
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Typical hard-faced parts (such as bearings) used in the atomic industry.

Combustion Engineering, Inc., New York, N. Y. (449)
Manufacturing facilities—reactor components—reactor vessel material samples.

The Conference Book Service, Arlington, Virginia (261)
Comprehensive exhibit of books of special interest, from various publishers.

Consultants Bureau, Inc., New York, N. Y. (313)
Scientific translations, Journal of Atomic Energy, etc.

Cooper Metallurgical Associates, Cleveland, Ohio (410)
Boron and other rare metals

Corning Glass Works, Corning, N. Y. (237)
Radiation shielding window.

Crane Company, Chicago, Illinois (337)
Specialized piping products for the atomic industry.

Crossroads Marine Disposal Corp., Boston, Mass. (427)
Miniature of company's plant.

Cuno Engineering Corp., Meriden, Conn. (316)
A modified filter cartridge which will be used in the Shippingport, Pa., reactor.

Curtiss-Wright Corporation, Metals Processing Division, Buffalo, New York (253)
High temperature alloy extrusions, castings and forgings.

Davison Chemical Company, Division of W. R. Grace & Co., Baltimore, Maryland (224)
Chemical and metallurgical materials and services in the atomic energy field. Emphasis on thorium and Rare Earth metals.

Dayless Manufacturing Company, Inc., Chicago 18, Ill. (209)
Floor cleaning appliances.

Daystrom Nuclear Division, Elizabeth, N. J. (404)
Reactor control instrumentation—reactor models.

The Edlow Lead Company, Columbus, Ohio (108)
Lead bricks and an isotope shipping cask.

ElectroData Division of Burroughs Corp., Pasadena, California (221)
E101 desk-size electronic digital computer. Descriptive material on the Datatron electronic high-speed digital computer and the Datafile.

(Continued on page 86)

ATOMIC EXHIBITORS

Encyclopedia Brittanica, Philadelphia, Pa. (326)
Encyclopedia Brittanica, plus accessories.

Energy Fund Incorporated, New York, N. Y. (257)
Leaflets, literature and charts.

Engelhard Industries, Newark, N. J. (258)
Gas indicators and purification equipment.

The Fenn Manufacturing Company, Hartford, Conn. (236)
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Finnell System, Inc., Elkhart, Indiana (123)
Diversified line of floor maintenance equipment and products.

Florida Development Commission, Tallahassee, Florida (115)
Nuclear-related activities underway in Florida.

Ford Instrument Co., Long Island City, N. Y. (220)
Models and details of closed-cycle, gas-cooled reactor.

Foster Engineering Company, Union, N. J. (305)

Foster Wheeler Corporation, New York, N. Y. (116)
Nuclear research reactor, nuclear power plant and components.

General Electric Company, Schenectady, N. Y. (400, 300, 301)
Designs of reactors, radiation instruments, electromagnetic pumps and allied products.

General Mills, Inc., Mechanical Division, Minneapolis, Minn. (265)
Mechanical arm (remotely controlled manipulator) and new fuel rod drive control mechanism.

The Griscom-Russell Company, Massillon, Ohio (164)
Model of a liquid metal heated steam generator.

Hamner Electronics Co., Inc., Princeton, N. J. (341)
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High Voltage Engineering Corp., Cambridge Mass. (420)
Particle accelerators for physics research and industry.

Industrial Laboratories, Chicago, Ill. (312)
Copies of Industrial Laboratories Magazine (March Issue).

The International Nickel, Co., Inc., New York, N. Y. (416)
Use of nickel and nickel alloys and electroplating in the atomic energy field.

Janney Cylinder Company, Philadelphia, Pa. (249)
Finished machined centrifugal castings of various ferrous and non-ferrous alloys.

Jordan Electronics, Inc., Alhambra, California (425)
Remote area monitoring system for radiation monitoring and portable radiation measuring instruments.

O. G. Kelley & Company, Boston, Mass. (324)
Shielding fabrication and installation techniques

Walter Kidde Nuclear Laboratories, Inc., Garden City, N. Y. (208)
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Kollmorgen Optical Corporation, Northampton, Mass. (111)
Industrial wall periscopes, binocular underwater periscopes and various instruments for remote observation.

Leeds & Northrup Company, Philadelphia, Pa. (470)
Working demonstration of the instrumentation for a simulated nuclear power plant.

Linde Air Products Company, Long Island City, N. Y. (336, 340, 342, 344)
Applications for the rare gases—neon, krypton, argon, helium and xenon—in nuclear materials processing, in reactor operations and in instrumentation.

Lindsay Chemical Company, West Chicago, Illinois (107 & 109)
Thorium and Rare Earth chemicals, and their applications.

Lukens Steel Company, Coatesville, Pa, (233)
Section of the clad steel plate which forms the walls of the Duquesne Light Company's atomic power station at Shippingport, Pa.

M.S.A. Research Corporation, Pittsburgh, Pa. (152)
Sodium potassium alloy, liquid metal pump, flowmeters, high temperature pressure gauges, etc.

McGraw-Hill Publishing Co., New York, N. Y. (124)
Nucleonics Magazine.

Mallinckrodt Chemical Works, St. Louis, Missouri (308)
Chemicals for the nuclear industry

Marchant Calculators, Inc., Oakland, Calif. (325)
Small electric calculators

Massachusetts Department of Commerce, Boston, Mass. (413)
Massachusetts research centers, colleges, recreation areas, maps and charts.

Metals & Controls Corporation, Attleboro, Mass. (405)
Atomic fuel elements and component parts.

Michigan Chemical Corporation, St. Louis, Michigan (429)
List of rare earth products related to the Atomic industry.

The Microcard Foundation, Madison, Wisconsin (140)
Microcard reading equipment and the new pocket-size Microcard Reader.

Minneapolis-Honeywell Regulator Co., Industrial Division, Philadelphia, Pa. (436, 440)
Full-size working reactor simulator with automatic startup.

National Carbon Company, Long Island City, N. Y. (336, 340, 342, 344)
High purity graphite for use in atomic reactors—nuclear graphite as used as moderator, reflector, shield.

National Electric Instrument Co., Inc., Elmhurst, New York (260)
Illuminated telescopic instruments for internal inspection of inaccessible areas.

National Industrial Conference Board, New York, N. Y.
Educational exhibit. Business research methods.

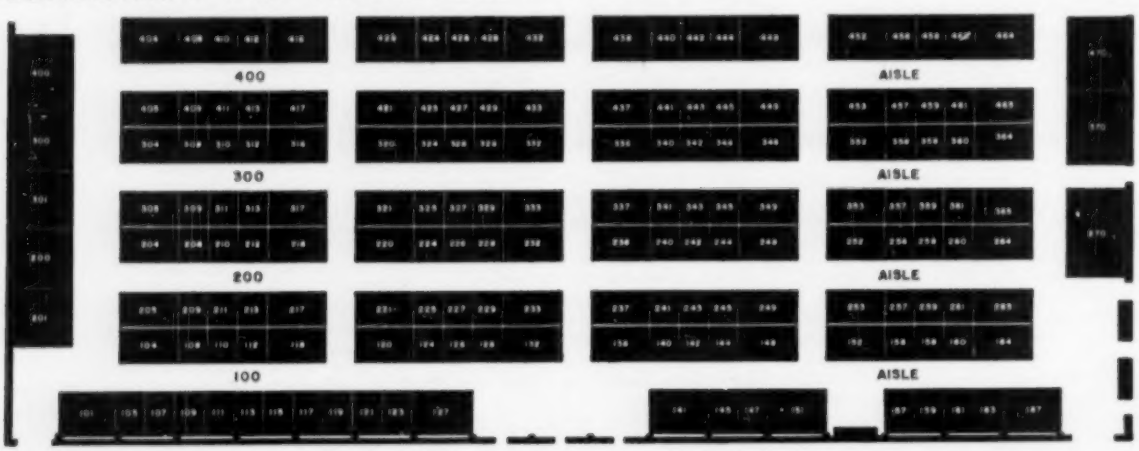
National Research Corporation, Cambridge, Mass. (432)
Activities of the NRC Equipment Corporation and the NRC Metals Corporation in the nuclear field.

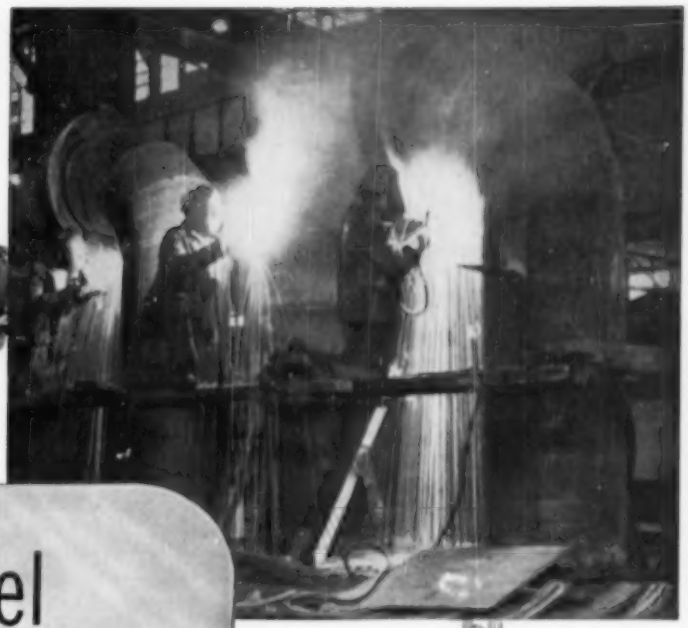
North American Aviation, Inc., Atomics International Division, Los Angeles, Calif. (104, 205)
Three dimensional working models of nuclear reactors.

Norton Company, Worcester, Mass (120)
Reactor Components—Ceramic fuel elements. Control elements and neutron shields. Heat barriers and refractory supports. Special refractories.

(Continued on page 88)

CONVENTION HALL FLOOR PLAN





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ATOMIC EXHIBITORS

(Continued from page 86)

Nuclear Development Corp. of America, White Plains, New York (412)
A critical facility and hot laboratory.

Nuclear-Electronics Corp., Philadelphia, Pa. (311)
Nuclear measuring instruments.

Nuclear Measurement Corp., Indianapolis, Ind. (445)
Proportional canning systems, air monitoring and survey instruments.

Oregon Metallurgical Corp., Albany, Oregon (144)
Zirconium and titanium castings for nuclear, corrosion resistant, and weight-saving applications.

Penberthy Instrument Company, Seattle, Washington (256)
Large radiation shielding windows. Lead glasses. Dense non-browning lead glass. Colorless lead glasses.

Penfield Mfg. Co., Inc., Meriden, Conn. (409)
Ion exchange equipment.

Pergamon Press, Inc., New York, N. Y. (437)
Representative scientific publications in the nuclear field.

The Pfaudler Company, Rochester, N. Y. (444)
6" diameter jacketed glassed steel digester. Section of glassed steel radiation shield. 10 gallon zirconium reactor.

Potter Aeronautical Corp., Union, N. J. (204)
Pottermeter sensing elements used in measurement and control of flow in nuclear research, development and reactor operation.

Radiation Counter Laboratories, Inc., Skokie, Ill. (157)
Two gamma ray spectrometers.

Saginaw Steering Gear Division, GMC, Saginaw, Michigan (349)
Ball bearing screws and ball bearing splines.

Selas Corporation of America, Dresher, Pa. (361)
Research and development facilities as applied to atomic energy programs.

Sylvania Electric Products, Inc., New York, N. Y. (321)
Unclassified nuclear fuel element shapes and other components such as control rods.

Technical Associates, Burbank, California (442)
Complete automatic personnel monitors as used by Argonne National Laboratory, Oak Ridge National Laboratory and Hanford Works.

Tracerlab, Inc., Boston, Mass. (370)
Tracerlab RLP-6 Stepwise Scanning Spectrometer System.

Union Carbide Nuclear Company, Long Island City, N. Y. (336, 340, 342, 344)
Samples of uranium ores and concentrates and three-dimensional models of power and research reactors.

U. S. Industrial Chemicals Co., Div. of National Distillers Products Corp., New York, N. Y. (217)
Zirconium, hafnium and sodium.

U. S. Naval Research Laboratories, Washington, D.C.
Design of reactors for transport service.

United States Steel Corporation, Pittsburgh, Pa. (353)
U. S. Steel Research, and stainless steel applications in specific, in the atomic industry.

D. Van Nostrand Company, Inc., Princeton, N. J. (411) Books (scientific).

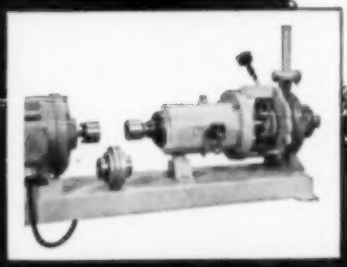
The Victoreen Instrument Company, Cleveland, Ohio (357)
Nuclear radiation controls and monitoring systems for reactor installations and radiation facilities.

Vitro Corp. of America, New York, N. Y. (320)
Uranium mining, milling, processing and design of nuclear facilities.

Westinghouse Electric Corp., Pittsburgh, Pa. (101, 105) Atomic components.

3 simple steps to service!

1.



Remove spacer from coupling.

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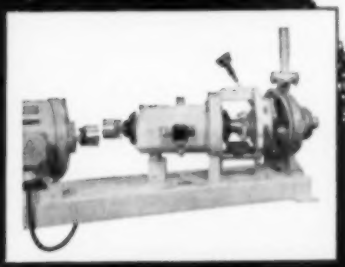
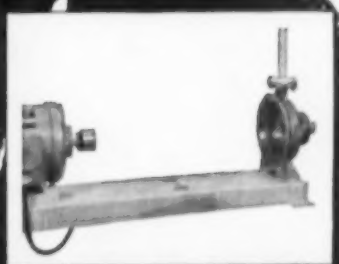
2.



Remove cap screws.

3.



Remove the pump. *Note:* Neither suction or discharge lines are disturbed, nor is motor or alignment affected.

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Bringing long experience in all phases of management and engineering to the analysis and discussion of the chemical industry's problems ten years from now, the panelists and speakers at A.I.Ch.E.'s Spring Management Meeting March 3-6 at West Virginia's magnificent Greenbrier resort hotel will answer your questions brought out by the highly-charged technical session.

- **A look into the future of products, processes, raw materials, selling, and labor relations.**
- **Computers in chemical company control.**
- **Opsearch—decisions and teamwork for engineers and management.**
- **Professional engineer licensing—its impact on chemical engineering.**

A major purpose of the Spring Management Meeting at luxurious White Sulphur Springs is to bring chemical engineers into contact with some of the best opinion and thought on just what they and their companies can expect over the next ten years in labor, products, processes, raw materials and sales. That means framing your questions and then getting together with the right man to help answer them. You're sure to meet a fellow expert in your field, and in just about every other field, too, and *CEP* is going to introduce you to the experts—with pictures so you can find them across the Greenbrier's ballroom.

Ten Years From Now

Two sessions are going to take a long look into the future of the chemical industry itself, what the engineer can expect to be happening then, what he must do now to prepare for it.

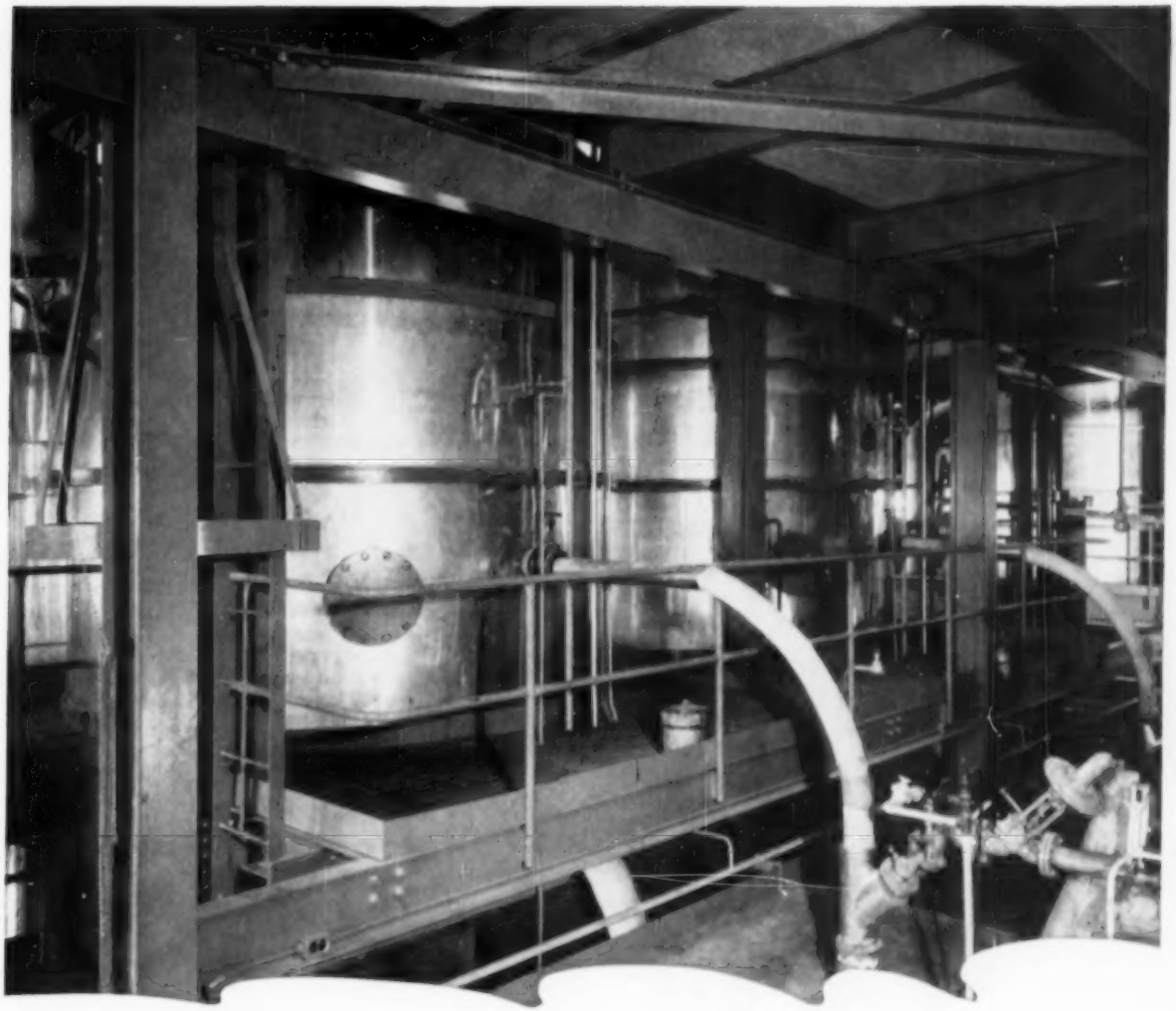
Leading the first session, **R. E. Chaddock,** chemical engineer and former manager of sales and market research for Hercules, now director of development for Hercules' Virginia Cellulose Dept. and president-elect of the Chemical Market Research Association, has gathered an experienced group of industrialists. **A. J. Greene,** administrative vice president and formerly director of development at Pfizer, will talk about the Future of Drugs and Biochemicals. Chemical engineer Greene, with Pfizer since 1938, is familiar with the trends and growths in this fast-changing industry. Chemical economist **Roger Williams, Jr.,** has been in industry, mainly on the cost and economics side, an editor of chemical journals, now has his own consultant firm of chemical economists, knows plastics. **E. H. Reichl,** long experienced in coal chemicals, will tackle the next ten years of this now basic industry. Chemstrand's active vice president and chemical engineer **F. J. Soday,** experienced in both research and development and administration on the top level in the field of plastics and synthetics, once operated a Government synthetic rubber plant.

HOW TO GET TO & FROM WHITE SULPHUR SPRINGS

The C & O railroad runs overnight pullman service from New York, making intermediate stops. The timetable shows White Sulphur Springs cars (occupied until 8:30 A.M.) leaving New York Mondays, Wednesdays, & Fridays. Other nights, one gets off train at 6:05 A.M. **CEP** is advised, however, that a number of extra pullmans, sufficient to handle reservation requests, will be added to accommodate all passengers to & from the convention. In case of question, call Mr. Joe Hartwyck, Pennsylvania Railroad, New York. PEnnsylvania 6-6000.

Like Chaddock, **George Rieger** of Diamond Alkali, heading the second session on the Future of the Chemical Industry, is experienced in market research as well as applications research. A chemical engineer, and Diamond's Director of Market Research, Rieger has also gathered a group of experts for his session. **I. H. Munro,** chemical engineer and vice president of Allied's Solvay Process Division, has been connected with the inorganic field for a long time. Joining Shell Chemical in 1931, chemist **R. L. Kittle** has been with the company ever since, except for a time with the Butadiene Section, Office of Rubber Reserve. Kittle is now manager of Shell's Manufacturing Operations Dept., knows where to look for The Future for Raw Materials for Organic Chemicals. **A. S. Brunjes,** manager, Technical Information

(*Continued on page 92*)



Another Conkey Crystallizer

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The *second* Conkey triple effect ammonium sulphate crystallizing system has been put "on stream" at Sherritt Gordon Mines Ltd. in Fort Saskatchewan, Alberta, Canada. Repeat orders such as this are based on performance . . . the proven success of Conkey Crystallizers to control the crystallization process and economically produce highest quality, optimum size, crystallizing products.

Conkey Crystallizers are designed and engineered to meet specific plant requirements. They are fabricated by Chicago Bridge & Iron Company in four strategically located, completely equipped plants.

Plan now to convert your by-product plant liquors into plant profits with "Conkey Know How". A Conkey engineer will be happy to assist you. Write the nearest CB&I office for complete information.

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WHITE SULPHUR MEETING

(*Continued from page* 90)

Dept. of the Lummus Co., is right at home in his subject—Tomorrow's Chemical Processing. "Market strategist" **A. P. Felton,** of Bruce Payne and Associates, is vice president and director of marketing for a company which specializes in long range planning of sales, personnel, plant and machinery, and entire growth programs for many clients in many industries. The Changing Picture in Chemical Selling is familiar territory for Felton.

Labor—Ten Years Ahead

The special Future Labor Trends in the Chemical Industry symposium has gone direct to leaders in the field. Presiding is Sloan School of Industrial Management's distinguished professor **D. V. Brown,** economist, writer on industrial relations and labor, a man who is experienced in all phases of labor-management relations, national and international. For labor, **O. A. Knight,** one-time refinery worker, official of the Oil and Chemical Workers International Union since 1937, presi-

Schwartz

Gregory

dent of Oil and Chemical Workers since 1940, vice president of CIO since 1947, is just about as high as you can go for labor's views in the chemical industry. For management—**F. H. Kirkpatrick,** who is no one-sided executive. He *is* an executive, but is also an educator, management consultant, former worker with the War Manpower Commission, civil service administrator, and now a member of the National Panel of the American Arbitration Association. For the Government, the Dept. of Labor has sent a distinguished lady, **Mrs. Aryness J. Wickens,*** labor expert, economist, educator, former Deputy Commissioner of the Bureau of Labor Statistics, and advisor at International Labor Conferences.

(*Continued on page* 94)

* Mrs. Wickens' title is Deputy Asst. Secretary for Employment and Manpower, U. S. Dept. of Labor, as listed in the program in *CEP*'s January issue. Her former title, Deputy Commissioner of the Bureau of Labor Statistics, was erroneously printed in the text in the same issue.

Photo courtesy Ross Heat Exchanger Division of American-Standard, Buffalo, N.Y.

"Because Ross Heat Exchanger Division has to be able to tell its customers how much cooling surface they're getting. That's a vital factor in a heat exchanger."

"I get it. That's why they use so many small tubes, instead of a few large ones. And Superior supplies the tubing?"

"Right. Stainless is the most popular, in ⅜ in. or ⅝ in. OD. But they order other analyses, too. The tubing has to have thin walls to perform the heat exchange function efficiently. It has to be strong to withstand the system pressure. And it's got to have smooth, clean inner and outer surfaces to minimize any pressure drop. Finally, it has to be tough, yet ductile enough to make installation easy."

Lend an ear, Mr. Design Engineer. They're talking about Superior tubing. The unit under discussion is made by Ross Heat Exchanger Division of American-Standard, one of the leading heat exchanger manufacturers. Superior tubing gives them the quality and dependability they like to build into their products.

This is only one of the many applications of Superior tubing in industry. We offer a wide range of tubing sizes in over 63 analyses, including stainless, carbon and alloy steels, nickel and nickel alloys, beryllium copper, titanium and zirconium.

Let us help you with *your* tubing problems. Our years of experience and our extensive facilities are at your service. For more technical information, write Superior Tube Company, 2011 Germantown Ave., Norristown, Pa., for your free copy of Bulletin No. 40.

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WHITE SULPHUR MEETING

(Continued from page 92)

Opsearch and Computers

G. D. Creelman, head of Creelman Associates, is again leading the operations research session. The former research coordinator of M. A. Hanna Co. is known to *CEP* readers from his biography in the January issue which printed the papers from his Pittsburgh symposium. Creelman, a leading apostle of Opsearch in the chemical industry, has on his program his psychologist senior associate **R. W. Wallen.** Ten years a professor of psychology at Western Reserve, Wallen has been especially concerned with the field of team psychology and in-group development, is active in National Training Laboratories, the leading organization working on in-group development. **E. W. Burr,** manager, Personnel Development, Monsanto, is well-schooled in the more active side of the field, is presently chairman of the Conference Workshop for Developing Leadership Skills being held at Arden House, New York, by the National Training Laboratories. Another former professor of psychology at Western Reserve, **O. A. Ohmann,** now director of Organization Planning and Management Development for Standard Oil (Ohio), is a noted expert on human relations among top level executives, has published a widely read article on the subject in *Harvard Business Review.* An actual report on Opsearch in practice is brought to the session by **C. C. VanderWall,** director of Manufacturing, Ansul Chemical. At Ansul, a firm of 550-600 employees, VanderWall and his fellow executives are applying social science principles to operations, have been doing so for the last six or seven years. Joining the first five men for the panel discussion is Monsanto's famous vice-president, sales executive, and top administrator, **F. J. Curtis,*** a long recognized expert in production, research, and administration.


Kuist


Neill


Hodge

W. M. Carlson, presiding at the computer session, is a chemical engineer in charge of Univac at Du Pont, where the test program includes

(Continued on page 96)

* Last month CEP erroneously "promoted" Curtis to president.

WHITE SULPHUR MEETING

(*Continued from page* 94)

management control, accounting, and technical applications. His fellow speakers, led by **W. A. Crichley,** controller of Diamond Alkali (which is deeply involved in integrated data processing), are equally versed in the field. **H. A. Hashbarger** and his co-worker **N. L. Sample** are closely connected with Monsanto's computer work which they will describe, analyze and discuss. The Polychemicals Department of Du Pont has spent 20 years developing its "cost rollup" accounting technique, is now applying computers. Both **R. L. Hershey** and **C. R. Schwartz** are deeply engaged in the work. Chemical engineer Hershey is manager of the Polychemicals Department, and accountant Schwartz is control manager, has led most of the specific work on the system. **R. H. Gregory** combines both areas involved in this session, being a chemical engineer and a CPA. Gregory has made a number of studies on data processing, has published widely in the entire field of computer applications.

Licensing the Engineer

Sunday's panel discussion promises to be one of the best Sunday sessions in recent meetings, due largely to the quality of the men involved. **D. L. Katz,** consulting engineer, professor of chemical engineering, chairman of Dept. of Chem. & Met. Engineering, Univ. of Michigan, will present the view of both the educator and the consultant on licensing. Director emeritus of the Engineering Experiment Station, U. of W. Va., **W. W. Hodge** is now chairman of the West Virginia Board of Registration for Professional Engineers. A senior Fellow at Mellon Institute, Hodge was also former dean of chemical engineering at West Virginia. Active **B. B. Kuist** of Fluor is one of A.I.Ch.E.'s most experienced men in the field of professionalism in engineering, was last year's A.I.Ch.E. representative on the EJC-ECPD Committee on The Practice of Engineering, is now an alternate on this committee and a member of A.I.Ch.E.'s Professional Legislation Committee. From a company long active in promoting professional registration of engineers, **E. T. Neill,** project manager at Dow, can be expected to present a strong pro-registration view. Moderator **T. J. Carron,** Ethyl, is the head of A.I.Ch.E.'s Detroit Section, has long experience in industry, is now more in the area of personnel activity which brings him to be moderator of this sure-to-be-lively panel.

A CEP roundup of what's happening in high temperature reactors for process heat . . .

"NUCLEAR TEST REACTOR GIVING 2,500° F. GASES CAN BE BUILT TODAY"

—says Ritzmann, of ORSORT study team.

"A nuclear test reactor to produce gases at 2,500° F. can be built today as a first step toward development of commercial reactors operating in this region," stated Robert W. Ritzmann (Koppers Co.) in an interview on this subject given exclusively to *CEP*. Occasion was discussion of Ritzmann's paper "Use of a Nuclear Heat Reactor as a Process Heat Source" delivered February 6 before the Pittsburgh A.I.Ch.E. local section and delivered in December 1956 before the American Nuclear Society.

"Understand," continued Ritzmann, "I'm talking about the use of materials and know-how that we have available right now. Shortly, we should be able to say we can go even higher, with 3,000° F. not far away."

Ritzmann's opinion arose from his experience on a seven-man ORSORT* study team† assigned the problem of conceptually designing a high temperature process heat reactor (full-scale). While ORSORT was so engaged, another group, consisting of personnel of Nuclear Development Corp. of America, (NDA) (a private contractor) were likewise at work under contract which called for: (1) determination from present technology the construction materials that appear feasible for use in a high temperature process heat reactor; (2) a conceptual design for a research process heat reactor, using the most promising of materials; (3) critical evaluation of the weakness and unsolved problems represented in the design, and from this a definition of the specific research and development needed to solve these problems.

Bureau of Mines Experiment

While the ORSORT and NDA projects were being carried on, the Bureau of Mines' Appalachian Experiment Station ‡ at Morgantown, W.Va. has been (and is still) conducting a program of materials testing, in an arrangement with AEC. Two experimental units have been used. One is bench scale, consisting of a refractory tube heated by a graphite resistance coil, to temperatures of around 3,000° F. Refractory materials have been tested in inert gases, steam, natural gas, etc. It is understood that metal carbides and silicides are showing considerable promise, considering that low neutron absorption is a quality which must be satisfied.

A larger experimental unit also in use consists of a refractory tube through which coal and other materials can flow, and which is heated by a surrounding induction coil. Coal slurry (maximum rate 20 lb. coal/hr.) is preheated to 1,000° F. and allowed to flow down the inside of the refractory tube. Entrained solids, slag, and carbonaceous ash are removed, while product gas is scrubbed before metering. Under consideration is separation of H_2 for direct hydrogenation of coal with gamma radiation serving to promote the reaction.

Economically Competitive Heat

That coal gasification may provide an early means of compensating for higher capitalization of nuclear heat sources is likewise indicated by the ORSORT study. Ritzman stated, "The group felt that such a reactor provided an excellent chance of being able to achieve an economically competitive heat source since relatively pure and expensive oxygen is used to obtain high temperature heat in existing processes."

For a 30,000 bbl./day coal hydrogenation petroleum refinery, the conventional oxygen process uses 14.8 tons of steam and 79.3 tons of oxygen to react with each 95.5 tons of coal to form 7,150 thousand cu.ft. of synthesis gas each hour. In ORSORT's nuclear steam process (see flow diagram) 140 MW of high temperature nuclear reactor capacity are added to heat 384 tons/hr. of steam from 2,040 to 3,000° F. This combines with only 50.2 tons/hr. of coal to again produce 7,150 thousand cu.ft. of synthesis gas. As 45% less coal is used, only 2.8 (in contrast with 5.3) tons/hr. of residue are produced.

The 3,000° F. steam temperature was arrived at in the following way: by selecting arbitrary temperature levels, permissible cost of reactor heat is calculated by dividing the savings by the reactor heat load. Results for nuclear reactor outlet temperatures ranging from 2,500 to 4,000° F. indicate little incentive to go above 3,240° F., or 1,000° F. above chemical reaction temperature. 3,000° F. seemed the forseeable materials limit.

Reactor inlet temperature also has an effect on permissible cost of nuclear

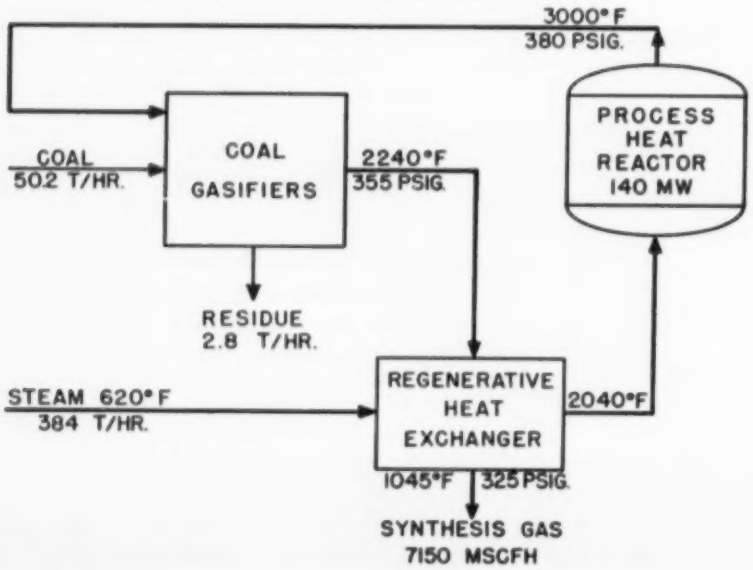
(*Continued on page* 100)

* Oak Ridge School of Reactor Technology.

† Other team members were J. T. Roberts (ORNL); J. S. Lagarias (Koppers); F. J. Remick (Penn State); J. O. Roberts (AEC); W. J. Roberts (Curtiss-Wright); & J. E. Schmidt (Westinghouse).

‡ The information on the NDA and Bureau of Mines programs appears in an article by Strimbeck, McGee, and Katell in *Amer. Gas Assn. Monthly*, October 1956.

Ritzmann's nuclear steam coal gasification process flowsheet.



AN IMPORTANT MESSAGE

to the customers and friends of Read Standard Corporation

Effective November 3, 1956, the Read Standard Corporation, 50-year-old manufacturer of Readco bakery and chemical processing equipment and Standardaire blowers, merged with and became a division of Capitol Products Corporation.

WHAT IS CAPITOL PRODUCTS CORPORATION?

Capitol Products Corporation is a young, progressive organization specializing in light metals fabrication. Principally, Capitol manufactures extruded aluminum products for the building industry. To date, this organization has enjoyed great success in both the manufacturing and marketing phases of its industry. For instance, in the highly competitive aluminum door business Capitol has become, in four years, the world's largest producer. This management now directs the Read Standard operation.

WHAT THIS MERGER MEANS TO YOU.

To you who know and have dealt with Read Standard, the merger means simply this . . . extensive research and development not only along present but completely new lines . . . broadened engineering, service and sales staffs to better handle your needs . . . and improved manufacturing facilities. As in the past, Read Standard will maintain office and plant operations at its location in York, Pa. Theodore F. Freed will be Vice President and Divisional Operations Manager of this Division.

To you whom we have served in the past, we wish not only to express our sincere appreciation but to affirm our policy. The prime objective of this Corporation is to make available to you the very best equipment and services that the ingenuity, modern research and manufacturing facilities of our combined operations can provide.

CAPITOL PRODUCTS CORPORATION

Eugene Gurkoff

Eugene Gurkoff
President

NUCLEAR PROCESS HEAT SOURCE

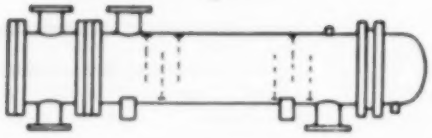
(*Continued from page* 98)

process heat, any heat added by the reactor to bring the steam up to 2,240° F. representing inefficiency. Efficiency is thus the ratio of heat used by the chemical reaction to that delivered by the nuclear reactor. Inefficiency is a function of the regenerative heat exchanger system. A 200° F. temperature approach shows a value of $1.32/MMBtu, and appears optimum. If recycled inert gas could be used for transferring heat without cooling for pumping, all the heat added by the reactor could be transferred to the chemical reaction and 100 per cent efficiency would result. Permissible cost would rise to $1.66/MMBtu, equivalent to steam for 22 mill/kw.hr. electric power. Reactor outlet temperature could be lowered to chemical reaction temperature of 2,240° F., plus the heat exchanger driving force of about 160° F., or 2,400° F.

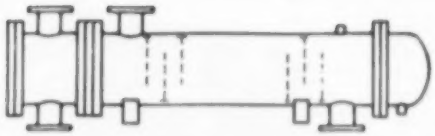
The ORSORT study, according to Ritzmann, speculated that maximum cost of this heat from a nuclear reactor would be $1.12/MMBtu, derived from a set of conditions which by inference are to be regarded as not too dissimilar from present utility reactor standards. This figure compares with $1.32/MMBtu permissible cost by the existing oxygen process.

The costs, Ritzmann feels, are higher than would be experienced with an actual reactor. A large critical mass is figured in because of the present inability to obtain a moderator to withstand high temperatures. Burn-ups higher than 10%, low costs of ceramic fuels, and avoidance of electric generating turbine equipment are looked to for savings. If process heat cost can be brought down to $0.83/MMBtu, the cost of gasoline produced would be lowered 0.6 cents/gal., or 5% of present manufacturing costs. On 1975 predictions, such nuclear heat could provide the basis for a large portion of our gasoline and substitute natural gas needs.

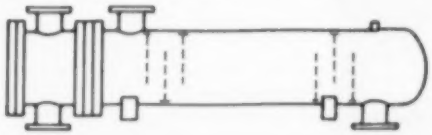
As the NDA report is classified, no comparisons are here possible. Asked for AEC's reaction to these feasibility studies, W. Kenneth Davis, AEC's director of Reactor Development, said, "AEC has under serious consideration the design and construction of an experimental reactor operating in the high temperature regions, one which would be primarily intended for use as a materials testing facility." This would seem to indicate that for practical purposes, there remains some proving to be done.



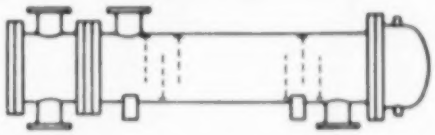
Type SG straight tube, outside packed lantern gland design. Eliminates undetected fluid inter-leakage.



Type S pull-through floating head design. For condensing, heating services . . . easy maintenance.

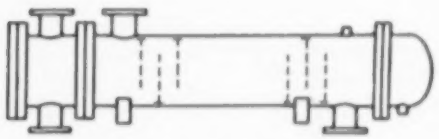


Type R U-tube design. Low cost construction, for non-fouling service.



Type ST conventional straight tube, split ring, floating assembly construction.

HOW YOU CAN SAVE WITH Whitlock Standardized Heat Exchangers!



Straight tube, fixed tube sheet design. Types V and V-1 — for easy mechanical cleaning.

SAVE WORK . . . "prints for approval" can be supplied quickly for piping and other layouts.

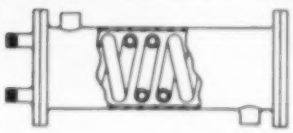
SAVE ENGINEERING COSTS . . . our engineers will help you select a standard design suited to your requirements.

SAVE DELIVERY TIME . . . many units can be manufactured promptly from stock materials and subassemblies. Also, completed units are often in stock for immediate shipment.

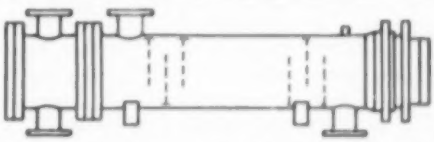
SAVE ON REPAIRS . . . readily available duplicate parts simplify emergency repairs . . . reduce downtime.

SAVE ON FIRST COSTS . . . our long manufacturing experience plus quantity produced sub-assemblies and quantity purchasing of materials reduce the unit cost of Whitlock Standard Exchangers. These savings are reflected in our current prices.

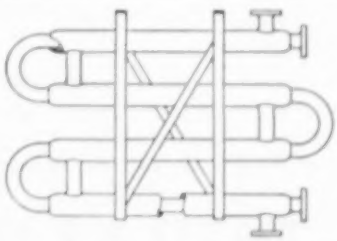
Compare costs . . . compare *savings*. It pays to consider Whitlock Standard Exchangers *first*. Send for Bulletin 250. The Whitlock Manufacturing Co. 97 South St., West Hartford 10, Conn.



Type C coil type heat exchangers. For high tube side pressures.



Floating head heat exchangers. Type SO with outside packed head — no concealed, bolted and gasketed joints.



Double pipe heat exchangers. For countertemperature flow conditions and low flow rates.

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Designers and builders of bends, coils, condensers, coolers, heat exchangers, heaters, piping, pressure vessels, receivers, reboilers.

INSTITUTIONAL NEWS

Now available from national A.I.Ch.E. are a series of published problems in chemical engineering. Designed for use in any and all chemical engineering schools, as well as industrial courses, the problems cover the subjects of: nuclear engineering; thermodynamics; filtration; humidification; crystallization; reaction kinetics; absorption, adsorption and extraction; distillation; and drying. Compiled by A.I.Ch.E.'s Chemical Engineering Education Projects Committee, each category of problems is in a separate booklet bound to fit a loose-leaf note book and each booklet sells for 25 cents. □

The Commercial Chemical Development Association's Honor Award and Annual Meeting will be held in the Hotel Statler, New York, N. Y. March 27-28, 1957. Subject will be plastics. □

Observing its twenty-fifth anniversary, the DeZurik Shower Co. of Sartell, Minn. is changing its name to DeZurik Corp. and placing several substantial new additions to its plant into operation. A prominent valve manufacturer to the chemical industry, DeZurik is changing its name to conform to its present diversified operations. □

The Annual Conference and Exposition for The Society of the Plastics Industry will run from March 17 through 21, 1957 at Biltmore Hotel and Shrine Auditorium in Los Angeles, Cal. □

A Colloquium on Radiation Effects on Materials will be held on the Johns Hopkins campus, Baltimore, Md., March 27-29, 1957. Sponsored by the Office of Naval Research and the Martin Co., the colloquium will present a series of unclassified educational review papers on the general subject of radiation effects on materials, will be organized to appeal to both the engineer and the research scientist. □

Do you have in your organization high school graduates who could help themselves and your company by learning the fundamentals of nuclear science and engineering? If you do, the new courses of International Correspondence Schools on nuclear energy fundamentals could be the answer for the men and the company. The possibilities are particularly valuable today when the country has an even greater shortage of trained technicians than it does of professional engineers. □

PHILOLOGY and FILTERAIDS

Joseph Conrad speaks of words "debased by centuries of careless usage," and a glance in any good dictionary does show that many of our everyday words no longer have any clear-cut meaning. This is particularly true in the field of filtration, where many people become confused between filteraid quality and filteraid grade. This confusion is probably compounded by the diatomite industry practice of naming their different filteraids, rather than designating them by a simple direct-reading grade designation.

We might better talk of filteraid efficiency – the ability to give maximum throughput with consistent clarity at minimum dosage. This high performance is essential both for your product quality and to hold operating costs in line. There are many cases where the production rate of an entire plant depends directly upon the output of the filter station. And high performance is a function of *both* quality and grade.

In diatomite filteraids, quality and grade are not the same thing. Every major filteraid supplier has available a series of grades, ranging from a fine particle size grade to a coarse particle grade, with flowrate increasing and clarity decreasing as the particle size increases. This series permits matching the filteraid to the characteristic of the feed liquor.

However, filteraids from different suppliers may be equivalent in grade but vastly different in quality or efficiency. The poor quality material may develop flowrate equal to the better material but be inferior in clarity. Or, clarity may be achieved at the expense of flowrate. The most common weakness, however, of poorer quality filteraids is their inability to cope with the occasional tough batch of liquor encountered in almost every plant.

This property – the ability to handle the tough batch, at economically sound dosage – is the true test of a top quality filteraid. This characteristic is not built into a filteraid by accident. It takes sound experimental work, based on years of experience in filtration, to develop the basic information as to particle size distribution and other characteristics required in a good filteraid. And, to make this knowledge effective, quality filteraid production must be backed by control of reserves of high quality raw materials, together with milling and sizing equipment which will process the material within the very narrow limits imposed by a system of rigid quality controls. To date, this is the only known method to insure top quality in diatomite filteraids.

P. W. Leppla
Technical Director

WKNL IN THE NEWS

NUCLEAR SHIELDING STUDY

Walter Kidde Nuclear Laboratories has just completed a field expedient shielding study for the Corps of Engineers, Research and Development Laboratories, Fort Belvoir, Va. While details of the work are classified, objective of the study was to gather basic data concerning shielding against neutron and gamma radiation, using materials available in military field operations.

It is expected that the results of the study will aid theoretical design and computation work for military applications of nuclear power plants.

• • •

NUCLEAR CONGRESS

WKNL is looking forward to the 1957 Atomic Exposition and Nuclear Congress, to be held in Philadelphia next month. Our exhibit will show some of the work we are doing as nuclear consultants on industrial applications of atomic energy.

WKNL projects currently include design and instrumentation of several novel nuclear power plants, two mobile reactor studies, experimental studies of moderator materials, hydraulic loop testing, development of a liquid mercury control system, application of fission products to production of light sources and miniature power sources, and research and development for the nuclear aircraft and commercial atomic power programs.

• • •

NUCLEAR EMPLOYMENT

Positions are available for qualified physicists, mathematicians, chemical and mechanical engineers. Write to Personnel Manager for information.

Consultants to industry on applications of nuclear technology

WALTER KIDDE NUCLEAR LABORATORIES, INC.

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SIX UNIVERSITIES TO AID IN EXPANSION OF OAK RIDGE NUCLEAR ENGINEERING SCHOOL

Classes to start this month at selected schools which are participating in program for accelerated training of nuclear reactor specialists.

To make possible expansion of advanced nuclear training provided by the Oak Ridge School of Reactor Technology (ORSORT)*, six universities have integrated into the program. These universities will take over the first half of the training previously given entirely at the government school. Two-year contracts are presently being negotiated with the schools to provide for concentrated courses of study to develop specific proficiency in chemistry, mathematics, physics, and engineering for students accepted for ORSORT.

"In the meantime," says J. F. Kaufmann, Chief of the Technical Assistance Section, Division of Reactor Development, AEC, "preliminary planning is well advanced and courses are scheduled to start in February of this year."

* See *C.E.P.*, September 1956.

The six schools, chosen out of 44 which submitted proposals, were: Carnegie Institute, Case Institute, Northwestern Univ., Univ. of Calif., Univ. of Florida, and Union College.

Starting in February, 1957, each of the selected universities will be assigned a minimum of 20 students. Successive classes totaling 120 students each will be assigned to the six schools in August, 1957; February, 1958; and September, 1958.

Each of the chosen schools has worked out in its own way the problem of integrating the two-semester system used at Oak Ridge with their own normal teaching schedules. According to Dr. Carl C. Monrad, Head of the Dept. of Chemical Engineering at Carnegie Tech., his school has solved the problem by instituting special summer sessions to assure the continuity of the nuclear courses.

It is the expressed hope of AEC that, after about four ORSORT classes, the universities will be in a position to take up the full burden and that, at that time, it will be possible to discontinue the Oak Ridge phase of the program.

AEC AID TO UNIVERSITIES IN FULL SWING

Action being taken on proposals from more than 50 schools.

Late last fall AEC announced "no-strings-attached" financial aid to universities for purchase of equipment and other teaching aids (see *CEP* September, 1956). The program was expected to total $3,000,000 for the fiscal year ending July, 1957.

J. F. Kaufmann, Chief of the Technical Assistance Section, Division of Reactor Development, AEC, revealed recently to *CEP* that his department (which administers the program) had recommended Commission action on more than 50 proposals received up to December 1, 1956. "If all the proposals received to date (mid-January) were to be accepted," said Kaufmann, "the provisional allocation of $3,000,000 would not begin to cover them all."

Most proposals have been for relatively small equipment; only if a university has an established program in nuclear engineering at a Masters level is it considered ready for a small reactor as a teaching aid. "Nevertheless," said Kaufmann, "several requests have been received for small reactors of the Argonaut* type (cost about $80,000)." The Commission hopes that grants for teaching aids can be continued for about five years, this being regarded as a realistic period of time to meet the growing demand for the university-trained product.

* The Argonaut is a water-moderated reactor using uranium enriched to 20%. It can operate at a maximum of 10kw of thermal power.

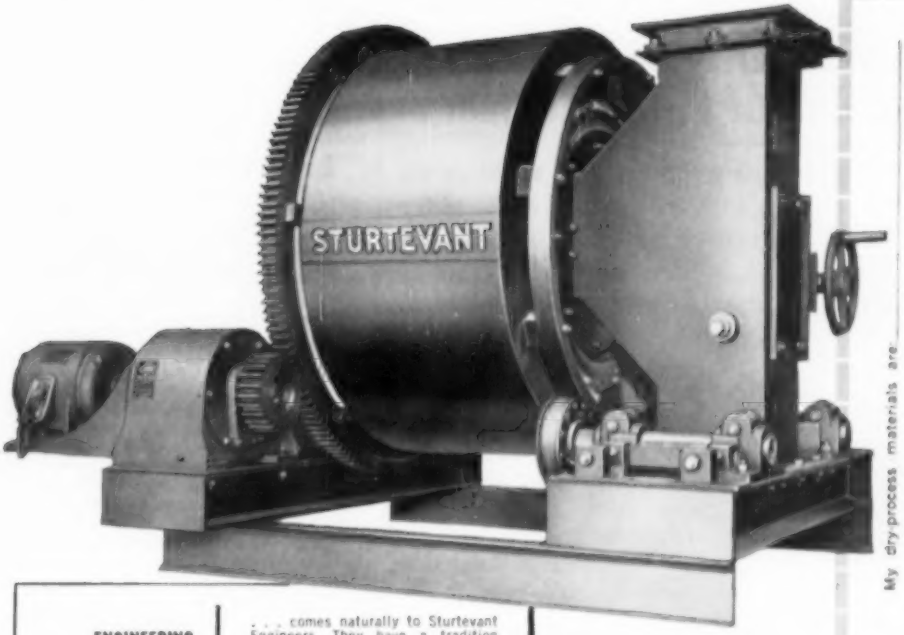
Faculty Training

Significant progress can also be reported for other phases of the AEC's assistance program. Under the faculty training section, approximately 90 teachers of engineering availed themselves in 1956 of the courses offered at the Summer Institutes for Engineering College Faculty given at the Brookhaven and Argonne National Laboratories. It is hoped to repeat the program during the summer of 1957, with the addition of specialized courses for advanced students. Special sections on separation techniques and reactor engineering should be of particular interest to chemical engineers.

Student Assistance

AEC envisages the granting of 150 special training fellowships in nuclear engineering technology. Courses will be given in private universities at a level comparable to that of the Argonne or Oak Ridge schools. Twenty-six schools have already been accepted and classes are expected to start in September.

COSTS OF BETTER BLENDS CUT TWO TESTED WAYS



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E-D Filter Paper Makes Excellent Cover For Cloth Or Other Filter Media

Provides Greater Clarity Of Filtration And Prolongs Life Of Filter Medium

FILTERTOWN, USA. Field reports prove that there is an increasing use of E-D filter papers, with the greatest demand for grade # 953, as a cover for cloth or other filter media in industrial filtration. To date, this practice has been widely adopted in plants which process oils, including coconut, cod liver, corn, cooking, linseed, soybean, and vegetable oil. These plants manufacture margarine, salad oil and shortening, soaps, paint, varnish, and many other products.

Great Savings In Time And Money

Actual experience, in hundreds of cases, has proven to the satisfaction of production officials that it is far more economical to cover the cloth or other filter medium with E-D filter paper and then, when the press needs redressing, to simply peel off the paper, discard it, and replace with a clean E-D filter paper cover. Substantial savings in press running time are made.

E-D filter paper holds up solid particles to such a degree that there is often little need for recirculating the slurry to obtain an adequate cake deposit for clear filtration at the start of a cycle.

Moreover, the E-D filter paper protects the filter medium from slimy fines, thus prolonging its useful life, saving additional money on media expenditures. The cost of E-D filter paper is so little, in comparison with the cost of other filter media, that these savings are important.

Greater Clarity Of Filtrate Obtained

Because of its fine porosity and unique uniformity of furnish, grade # 953—as well as the many other grades of E-D filter paper—obtains exceptional clarity of filtrate. Many degrees of rapidity and porosity are available in the more than 50 regular grades manufactured by The Eaton-Dikeman Company. Special grades are also made to meet individual requirements.

Free Samples Available

Actual tests made at the user's plant furnish convincing proof of the many advantages that are possible. Simply write for E-D's Filtration Analysis Report. When the necessary facts are supplied, you will receive several recommended grades, cut to your own size and specifications, at no charge. Make the necessary test runs and you will soon be able to determine the benefits for yourself. There is no charge or obligation for this service.

Write to Thomas H. Logan, Jr., care of The Eaton-Dikeman Company, Filtertown, Mount Holly Springs, Pennsylvania for prompt attention.

This company is the only company in America that is exclusively engaged in the manufacture of filter paper for science and industry. Authorized representatives and dealers are located in every section to provide service and helpful information on all problems relating to liquid filtration.

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NUCLEAR CONGRESS PROGRAM

(Continued from page 82)

RADIATION PROCESSING: Chairmen: P. N. Powers, A. V. Peterson. **Use of Ionizing Radiations in Control of Parasitic Infections.** J. Villella, H. J. Gomberg and S. E. Gould, Univ. of Mich. **Basic Concepts in the Application of Ionizing Radiations to Foods For Preservation.** D. H. Rest, B. H. Morgan, G. E. Danald, G. E. Tripp, M. Simon, Quartermaster Corps, U. S. Army. **A Megacurie Cobalt 60 Food Irradiator.** Procedures for installation, servicing, and operation. B. Manowitz, O. A. Kuhl and L. Galanter, Brookhaven. **Peacetime Utilization of Ionizing Radiation to the Chemical Industry.** Applications to plastics, rubber, oil, and other chemical industries. K. H. Sun, Westinghouse. **The Nuclear Reactor as an Instrument of Medical Research and Therapy.** Major equipment and procedures for medical experimentation. E. Stickley, G. S. Robertson, L. E. Farr, Brookhaven.

A.I.Ch.E. FUEL CYCLE SESSION 5, FUEL PROCESSING—NON-AQUEOUS: Chairmen: S. Lawroski, S. M. Stoller. **Liquid Metal Fuel Reactor (LMFR) In-Pile Fuel Processing Loop.** Degassing and salt contacting procedures in removing fission product poisons. C. Raseman, H. Susskind and G. H. Waide, Brookhaven. **Decontamination of Irradiated Uranium by Fluoride Volatility Process.** W. J. Mecham, R. W. Kessie, W. B. Seefeldt and R. C. Liimatainen, Argonne. **Magnesium Extraction Process for Plutonium Separation from Uranium.** A high-temperature extraction process. I. O. Winsch and L. Burris, Jr., Argonne. **Conceptual Design of Pyrometallurgical Reprocessing Plant.** Fuel reprocessing by oxidative slagging. L. Basel, United Engineers & Constructors and J. Koslov, Vitro. **Conceptual Design of Remote Fabrication Plant.** C. M. Ladd, APDA, and J. Koslov, Vitro.

REACTOR DESIGN: Chairmen: L. Macklin, D. J. Woodruff. **Engineering Aspects of the Nuclear Design of Power Reactors.** Analysis methods for a heterogeneous, water cooled and moderated thermal reactor. M. J. Galper and O. J. Woodruff, Jr., Westinghouse. **Nuclear Powered Gas Turbines for Light Weight Power Plants.** Evaluation of plants for power outputs in the 600 to 60,000 HP. range. F. Hammitt and H. A. Ohlgren, Univ. of Mich. **Design and Construction of the Engineering Test Reactor.** P. D. Bush, Kaiser. **Stress Corrosion Cracking Problems in the Homogeneous Reactor Test (HRT).** E. G. Bohlman and G. M. Adamson, Oak Ridge.

WED., MARCH 13 (P.M.)

REACTOR CORE DESIGN: Chairmen: W. K. Davis, W. J. McCarthy, Jr. **EBR-II Control System.** E. Hutter, Argonne National Laboratory. **On the Significance of Reynolds Number on Reactor Design.** F. L. Jackson, J. P. Waggener, J. S. Busch, L. H. Harman, Westinghouse. **Absorber Materials for Reactor Control.** W. K. Anderson and D. N. Dunning, Knolls.

URANIUM METALLURGY AND RADIATION EFFECTS: Chairmen: B. Lustman, C. A. Bruch. **The Effect of Cooling Rate on the Nucleation and Growth of Beta Uranium Hydride in Metallic Uranium.** Application of the Jominey end-quenching technique. H. R. Gardner and J. W. Riches, G.E. **Effects of Alloying Element Additions of Al, Si, Mo, Ti, V, Zr and Nb on the Thermal Cycling Stability of Uranium.** S. T. Zegler and H. H. Chiswik, Argonne. **Metallographic Studies on Neutron-Irradiated Non-Fissionable Metals.** C. A. Bruch, W. E. McHugh and L. J. Doig, Knolls. **Effects of Grain Size on the Growth of Alpha-Uranium Under Irradiation.** R. Resnick and L.

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NUCLEAR CONGRESS PROGRAM

(Continued from page 106)

Seigle, Sylvania Elec. Prod. **The Effect of Irradiation on the Tensile Properties of Uranium.** R. E. Hueschen, R. S. Kemper and S. K. Kelly, G.E.

REACTOR PLANT INSTRUMENTATION: Chairmen: E. E. Lynch, T. S. Gray. **Health Physics Instrumentation for a Power Reactor.** G. H. Whipple, Univ. of Rochester. **A Resistance Temperature Detector for Nuclear Reactor Service.** F. R. Sias, G.E. **Safety Circuit Development at Brookhaven National Laboratory.** J. E. Binns, W. Lones and D. G. Pitcher, Brookhaven; M. Melice, Nuclear Development Corp. of Amer. **Recent Developments in Nuclear Instrumentation at the Knolls Atomic Power Laboratory.** Ultrasonic transducers, electronic pulse circuits and indicator. R. S. Stone, G.E. **Ultrasonic Flowmeter Monitors Reactor Heat Exchange Circulation.** M. Koblenz, R. M. Spiegel, S. Kass and H. Sterling, Fischer & Porter. **Radiation Flux Conditions in Radioactive Media with Applications to Radiation Monitoring.** B. E. Dahlin, Minneapolis-Honeywell.

HIGHLIGHTS FROM THE FIRST WINTER MEETING OF THE AMERICAN NUCLEAR SOCIETY IN WASHINGTON: Chairmen: C. R. McCullough, Exec. Vice President, Amer. Nuclear Soc. **Thermonuclear Reactions,** A. C. Kolb, NRL. **Reactor Theory,** A. M. Weinberg, Director, ORNL. **Reactor Kinetics—Experimental,** F. Schroeder, Phillips Petroleum. **Reactor Engineering and Plant Design,** J. W. Landis, Babcock & Wilcox. **Engineering Problems in Reactor Containment,** L. J. Koch, ANL.

A.I.Ch.E. FUEL CYCLE SESSION 6, FUEL CYCLE ECONOMICS: Co-Chairmen: M. Levenson, J. Hogerton. **Fuel Processing and Recycling for Natural Uranium Power Reactors.** H. K. Rae, A.E.C.L. **The Economics of Ceramic Fuel Elements.** J. R. Johnson, Minnesota Mining and Manufacturing. **The Economic Background for the Competitive Development of Nuclear Power.** H. W. Nelson and W. R. Keagy, Jr., Battelle. **Some Fuel Fabrication Economics Parametric Studies.** D. Kallman, Babcock and Wilcox. **Decay and Storage of Irradiated Fuel.** J. W. Ullman and E. D. Arnold, Oak Ridge.

WEDNESDAY, MARCH 13, 7:00 p.m.

All-Congress Banquet. Bellevue-Stratford Hotel, Ballroom, Broad and Walnut Streets, Philadelphia. Price $10.00. (Speaker to be announced). Ladies Welcome.

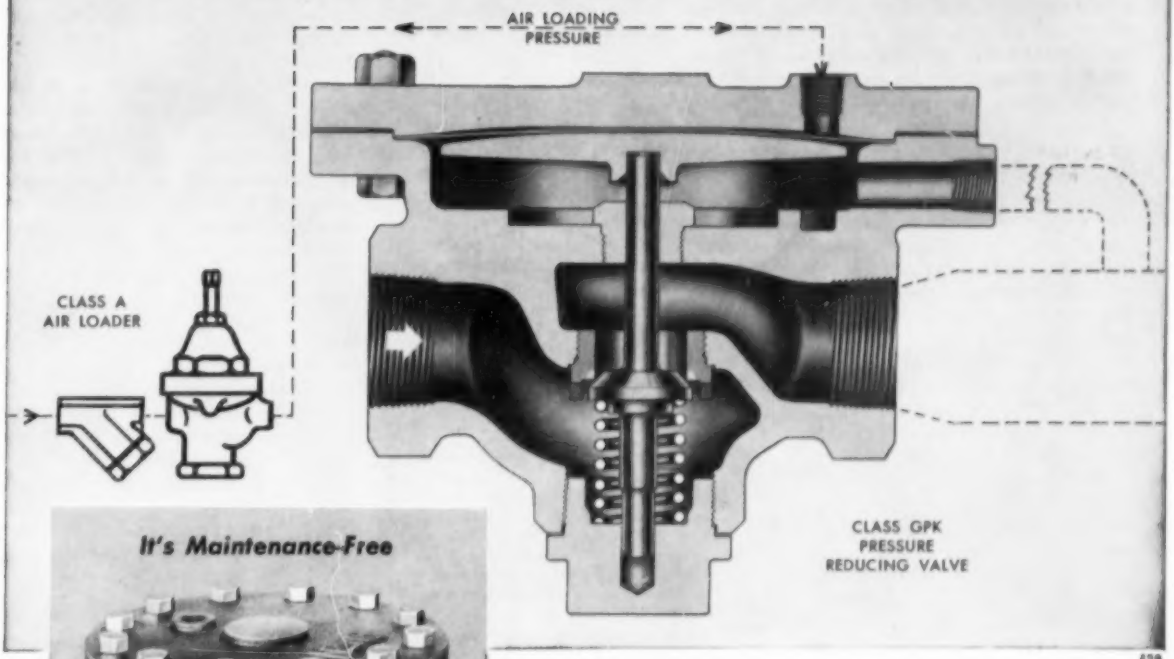
THURS., MARCH 14 (A.M.)

REACTOR CONTROL AND SIMULATORS: Chairmen: R. Oldenburger, M. A. Schultz. **Dynamic Simulation of a Fast Reactor System.** Use of analog computer techniques. R. G. Olson, APDA. **Control Problems in Sodium Cooled Graphite Moderated Reactors.** J. E. Owens, Atomic Internat. **The Development of a Universal Type Control Drive Mechanism for Nuclear Reactors.** C. Hinrichs and G. Rolan, American Machine & Foundry. **The Logarithmic-Diode Counting-Rate Meter and Period Meter.** B. B. Barrow, Hycon Eastern.

NATURAL RESOURCES I: Chairmen: L. R. Page, R. L. Faulkner. **Exploration, Resources and Production of Uranium.** R. D. Nininger, AEC. **Recent Advances in the Geology of Uranium Developments in Geochemistry and**

(Continued on page 112)

No maintenance inspection on this new valve until 1959!



You can just put this amazingly simple and compact Leslie Class GPK-A pressure reducing valve on the line and forget it for at least 3 years!

YES, AND THAT'S A *GUARANTEE* backed by a reputation for quality established in more than half a century of design, development and manufacture of regulators and controllers.

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A simple air loader eliminates the conventional bulky loading spring and provides accurate diaphragm loading that gives pilot-type response. Yet, it is rugged and uncomplicated. The unit itself lends itself readily where remote adjustment is an advantage, too. And you pay no price premium for these advantages. You get Leslie quality for about the same initial cost as leading makes of ordinary regulators.

Suitable for any steam service up to 250 psi, 450°F, the unit is available in ½" to 2" sizes. It is ideal for intermittent service too, and is unaffected by dirty steam.

Your Leslie engineer can give you all the data on this amazing valve. You'll find him listed in your classified directory under "Valves" or "Regulators"

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Will

REVOLUTIONARY TRENDS IN PULP AND PAPER TECHNOLOGY

be developed in time, be adopted for the industry's new multi-billion-dollar expansion?

Industry leaders advocate new plant designs embodying latest advances in chemical engineering techniques, ask for accelerated development program, but worry about manpower.

Now the fifth largest, and third-fastest growing, industry in the country, the pulp and paper industry (and the role of the chemical engineer in its future) was analyzed and discussed at the recent Boston Annual Meeting.* All panel members agreed that the industry is in a state of change, is becoming more a science than an art, is going to depend more and more on the engineer, particularly the chemical engineer. Taking the strongest view, Canada's Thiesmeyer said the technology of the industry is on the verge of a revolution.

Major changes involved in this impending technological revolution, according to Thiesmeyer, will be three: 1) the merging of mechanical and chemical pulping; 2) conversion of chemical pulping from batch to continuous operations at very high speeds, probably in smaller units at the lumbering sites; and 3) addition of by-product chemicals processing to the major activities of the industry through the utilization of its liquid wastes.

Present Problems

Practical paper man Olmsted, president of S. D. Warren, agreed that the industry is in rapid growth, will see many changes in technology, will undoubtedly increase at least 65% over the next 20 years. But, Olmsted warned, it won't be easy to accomplish. Management in the industry is confronted with some real problems that may prevent immediate (2-10 years according to Thiesmeyer) introduction of new technology. There is the ever-present raw material problem; the money problem; and the manpower problem.

The money problem is pointed to by Olmsted, "If the industry has 20 million tons or more of new capacity to build in the next 20 years, it will cost $10 billion . . . a very large part of this must come from profits retained in the business . . . how much profit can we retain?"; and Thiesmeyer, ". . . the chief reason why the new methods do not sweep the industry is because such huge capital investments as are represented by the conventional batch plants cannot be written off suddenly and without sharp dislocation in the industry's economy."

April CEP will feature details of the **Revolutionary Trends in Pulp and Paper Technology,** plus forecasts of economic and other problems influenced by the degree to which chemical engineering techniques are adopted by the industry.

On the manpower problem, the speakers were unanimous: the industry is going to need a large increase in technical manpower, both mechanical and chemical engineers, with chemical engineers in growing demand as the technology changes are introduced.

Chemical Engineers and Paper Techniques

Both Institute of Paper Chemistry's Whitney and University of Maine's Jenness emphasized that chemical engineering is already important in the pulp and paper industry, will become more so in the future, will call for the services of many more chemical engineers than are now in the industry, and will demand far more training of chemical engineers specifically for the industry.

Jenness, analyzing training on the undergraduate level, presented figures to show that less than 1% of the nation's engineers were employed in the paper and pulp industry in 1956. Even if these were 50% chemical engineers, it would mean only two chemical engineers for each paper and pulp plant —far too few for the technological changes forecast for the industry.

Many chemical engineering graduates enter the pulp and paper industry, some with training in the industry, most with little. Perhaps, Jenness pointed out, the need for chemical engineering training in the industry is best seen by the demand for the graduates of pulp and paper curricula who *do* have considerable chemical engineering training. At Maine, where chemical engineering courses are part of the pulp and paper discipline, 88 companies came last year to interview the 23 graduates who sought positions in the pulp and paper field. All were placed!

Of the six institutions offering undergraduate courses in pulp and paper technology,* *all* give some work in chemical engineering, and Lowell Technological Institute's Prof. Lewis says, "a man with the training of the chemical engineer . . . will fit into more positions in the paper industry than a man with any other single type of training."

It is clear that six schools cannot supply the needs of the entire paper and pulp industry, and, Jenness emphasizes, "the paper industry today promises a challenging future for the chemical engineer . . . more young men will recognize these opportunities early enough to prepare for them."

Even less attention has been paid to graduate training for the industry, Whitney points out. His own Institute, plus the University of Maine, are the only two offering graduate degree programs, and both are heavily weighted with chemical engineering work. Yet it is the experienced engineer who is needed in the changing industry today, and graduate work can help prepare him for the transition.

A paper research executive, speaking from the floor at the meeting, emphasized that he would prefer men with some five years or more experience in chemical engineering in other fields, notably chemicals or petroleum. "These men," he said, "have tremendous qualifications for employment in the pulp and paper industry."

As Thiesmeyer said, "The chemical engineer can play a dominant role in the changes coming in the pulp and paper industry. Projected growth of the industry places it among the major career opportunities open to chemical engineers at the present time."

* Boston, December 12, 1956. E. C. Bowen, Bowen Corp., presiding; G. Olmsted, Jr., S. D. Warren Co.; L. C. Jenness, Univ. of Maine; R. P. Whitney, Institute of Paper Chemistry; and L. R. Thiesmeyer, Pulp and Paper Research Institute of Canada. Panel discussion: J. W. Hemphill, Pulp and Paper Div., Johns Manville; H. G. Ingraham, Pulp and Paper Division, Chas. T. Main, Inc.; W. A. Ketchen, The Fraser Companies, Ltd.; W. Pittam, Pulp and Paper Div., Stone & Webster Eng. Corp.; R. A. Springer, Research Center, Diamond Alkali.

* Western Michigan College, North Carolina State College, New York State College of Forestry (Syracuse U.), Lowell Technological Institute, Univ. of Alabama, and the Univ. of Maine. The Universities of Florida and Washington also do some work in pulp and paper and some of their chemical engineers go into the industry.

J-M 85% Magnesia is lightweight . . . easy for workmen to install half-sections on this 10" steam line. Insulation work at the Grace Chemical plant was performed by Young Sales Corporation of St. Louis. Engineering and construction was directed by Foster Wheeler Corporation of New York.

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J-M 85% Magnesia also comes in block form. Here you see it being applied to a vertical drum at a New Jersey petroleum refinery.

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Johns-Manville *first-in* **INSULATION**

MATERIALS · ENGINEERING · APPLICATION

NUCLEAR CONGRESS PROGRAM

(Continued from page 108)

Mineralogy. R. M. Garrels, Harvard. **Laboratory Investigations on the Origin of Uranium and Vanadium in the Ores of the Colorado Plateau.** A. M. Pommer, U. S. Geol. Survey. **Crystal Chemistry of Carnotite.** P. B. Barton and D. E. Appleman, U. S. Geol. Survey. **New Developments in Methods of Radiometric Assay for Uranium.** Experimental results and details of theory and apparatus. H. L. Volchok, Isotopes, Inc.

METALLURGY OF REACTOR MATERIALS: Chairmen: A. R. Kaufman, B. Dunnington. **Transformation Kinetics and Mechanical Properties of 0.5 and 1.0 w/o Molybdenum-Uranium Alloys.** E. G. Zukas, Univ. of Calif. **The Metastable Gamma Phase in Uranium Base Molybdenum Alloys.** W. A. Bostrom and E. K. Halteman, Westinghouse. **The Corrosion of Uranium-Molybdenum Alloys in High Temperature Water.** M. W. Bukart and I. Cohen, R. K. McGeary, Westinghouse. **Self-Diffusion in Thorium.** C. J. Meechan, North American Aviation. **Internal Friction and Shear Modulus of Thorium at High Temperatures.** C. E. Dixon and H. Hori, Atomics Internat. **Effect of Cold Work on the Mechanical Properties of Zircaloy-2.** F. Forscher, Westinghouse.

HEAT TRANSFER AND HEAT EVOLUTION: Chairmen: Lee Chajson, Ken Coulter. **Nusselt Values for Estimating Turbulent Liquid Metal Heat Transfer in Non-Circular Ducts.** J. P. Hartnett and T. F. Irvine, Jr., Univ. of Minn. **Natural Convection Inside Horizontal Cylinder.** W. R. Martini and S. W. Churchill, Univ. of Mich. **The Integral-Spectrum Method for Gamma Heating Calculations in Nuclear Reactors.** L. G. Alexander, Oak Ridge.

NAT'L. INDUS. CONFERENCE BD. 5TH ANN. ATOMIC ENERGY IN INDUSTRY CONFERENCE. PART 1: Developing Better Products Through Radioisotopes. Prospects for Economic Nuclear Power—Part I. Projections through 1980. **Reactor Hazards, Public Safety and Insurance. Atomic Age Metals Create New Markets.** Metals being developed for nuclear field are creating additional markets for products and equipment used in their preparation.

THURS., MARCH 14 (P.M.)

NATURAL RESOURCES II: Chairmen: C. A. Anderson, P. F. Kerr. **Patterns of Disequilibrium in Radioactive Ores.** J. H. Rosholt, U. S. Geol. Survey. **Zirconium: Mineralogy and Geochemistry.** C. Frondel, Harvard. **Environment of Some Wyoming Uranium Deposits.** E. W. Grutt, Jr., AEC. **Uranium West of the Colorado Plateau.** D. L. David and B. J. Sharp, U. S. Atomic Energy Div. **Recent Uranium Redistribution in the Cameron, Arizona Deposits.** R. Austin, AEC. **Natural Occurrence of Thorium.** G. Phair, U. S. Geol. Survey.

PROBLEMS RELATED TO HEAT TRANSFER: Chairmen: S. W. Churchill, R. V. Bailey. **Transient Thermodynamics of Reactor and Process Apparatus.** Application to a boiling water reactor, a flash tank of a dual cycle power plant and the pressurizer of the pressurized water reactor. D. H. Brown, Knolls. **Electrical Problems in Electrical Burnout Testing of Nuclear Fuel Elements.** T. W. Hunt, Westinghouse. **Mechanical and Thermal Problems of Water Cooled Nuclear Power Reactors.** N. J. Palladino and J. Sherman, Westinghouse. **The Time and Temperature, Dependence of Thermal Stresses in Cylindrical Reactor Fuel Elements.** K. R. Merck, G.E.

METALLURGY OF URANIUM-ZIRCONIUM AND URANIUM-NIOBIUM ALLOYS: Chairmen:

(Continued on next page)

H. A. Wilhelm, H. H. Chiswik. **The Effect of Oxygen on Zirconium-Uranium Epsilon-Phase Alloys.** A. A. Bauer, F. A. Rough and H. A. Saller. **The Transformation Kinetics of Uranium-Zirconium Alloys Containing 50 and 60 w/o Uranium.** J. J. Kearns, Westinghouse. **The Corrosion Properties of Zirconium-Base Fuel Alloys.** S. Kass, Westinghouse. **Corrosion Behavior of Intermediate Uranium-Zirconium Alloys in High-Temperature Water.** K. M. Goldman and S. Kass, Westinghouse. **Uranium-Columbium Alloy Diagram.** B. A. Rogers, D. F. Atkins, E. J. Manthos and M. E. Kirkpatrick, Iowa State College. **Continuous Cooling Transformation Studies for The U-10 wt % Nb Alloy.** J. S. Parry, R. J. Van Thyne and D. J. McPherson, Ill. Inst. of Tech. **Effects of Irradiation on Powder Compacts of Uranium and Some Uranium-Base Alloys.** J. H. Kittel and S. H. Paine, Argonne. **Radiation Stability Studies of Binary Uranium Alloys.** G. D. Calkins, J. E. Gates, A. A. Bauer and F. A. Rough, Battelle.

REACTOR INSTRUMENTATION DEVELOPMENT: Chairmen: G. W. Morton, H. A. Lammonds. **A Wire-Activation Technique for Reactor-Flux-Profile Measurements.** A. E. Klickman, Battelle, and F. R. DeFalco, Westinghouse. **Development of a Thermal-Neutron-Flux-Measuring Instrument.** C. V. Weaver, C. K. Smith and J. W. Chastain, Battelle. **Solid-State Neutron-Flux Measuring System.** T. S. Gray, R. H. Spencer, M.I.T.; W. M. Grim, Jr., General Electronic Lab., and F. S. Replogle, Jr., Schlumberger Well Surveying. **Acoustic Ionization Chamber.** D. R. Whitehouse and F. S. Replogle, Jr., M.I.T. **Millimicrosecond Coincident System.** Measurement of positron lifetime. J. G. Lundholm, Jr., J. A. Bjorkland and A. C. Menius, Jr., North Carolina State College. **Evolution of Neutron Sensing Elements—Scientific Laboratory to Industrial Application.** Materials, techniques, design. L. Johnson, Neutronics Lab.

NAT'L. INDUS. CONFERENCE BD. 5TH ANN. ATOMIC ENERGY IN INDUSTRY CONFERENCE. PART 2: New Products Through Radiation Chemistry. Prospects for Economic Nuclear Power—Part II. How Can Market Potentials in Atomic Energy be Realized? Equipment, radiation facilities, research reactors, and instruments. **Atomc Energy Legislation (panel).** Experience under the Atomic Energy Act; changes that seem needed.

FRI., MARCH 15 (A.M.)

HOT LABORATORY FACILITIES: Co-Chairmen: F. Ring, Jr., H. G. Duggan. **The Design and Construction of the Enlarged Westinghouse Hot Laboratory.** A. L. Maharan, Westinghouse. **A New Hot Metallurgical Laboratory at Los Alamos.** J. R. Lilienthal, R. E. Field, E. D. King and D. Murphy, Los Alamos Scientific Lab. **Hot Laboratory Facilities Westinghouse Testing Reactor.** R. J. Catlin, Westinghouse. **A Laboratory for Reactor Development and Applied Radiation Studies.** C. J. Roberts, Curtiss Wright. **General Electric's Radioactive Materials Laboratory at Vallecitos.** J. Frame, G.E. **Decontaminable Surfaces and Procedures for Hot Cells.** C. D. Watson, Oak Ridge. **Management and Operation of a Privately Owned Hot Cell Facility.** G. D. Calkins & J. E. Whitney, Battelle.

EQUIPMENT FOR HOT MECHANICAL AND METALLURGICAL OPERATIONS: Co-Chairmen: P. F. X. Dunigan, L. D. Turner. **Designing a High Gamma Radiation Facility.** A. Deutsch, Budd. **Technique for Making Visual Examinations and Dimensional Measurements at Hanford's Radiometallurgy Laboratory.** D. L. Zimmerman, G.E. **Remotely Controlled Lathe.** C. C. Leader, Jr., G.E. **Hanford's Improved Re-**

(Continued on page 116)

NUCLEAR MANPOWER NEEDS

- **How big is our present nuclear industry?**
- **How big will it be in the near future?**
- **What is the basic educational background of the people now employed in our nuclear industry?**
- **In which direction should our major educational and training program be directed?**

To answer these and other questions vital to our nuclear development, the AEC is making an extensive survey of professional manpower needs in industry, government and universities.

A nation-wide survey of present and future manpower needs in the nuclear field is being made by AEC. This is an all-encompassing effort to determine these needs numerically, by basic profession and specialized training, by type of employer. It is anticipated that the data collected and the conclusions drawn therefrom will provide a solid basis for the planning of educational and training programs.

Supervision and coordination of the survey is in the hands of K. S. Colmen of the Organization and Personnel Division of AEC. For the final preparation of the master report, expected to be available by next fall, aid may be forthcoming from the Bureau of Labor Statistics or other government agency.

The survey has been divided into four parts, each served by separate mailings of basically similar questionnaires.

Private Industry-Supported Nuclear Activities

Mailing under this first category has been subcontracted to the Atomic Industrial Forum, Inc., which also supplied the mailing list based on Access Permit holders, A.I.F. membership and conference attendance. For this section of the survey approximately 3,000 questionnaires were sent out; about 1,000 have already been returned. Of these 1,000, about 250 companies have reported programs involving the employment of scientists and engineers in nuclear activities.

Universities

Section two of the survey dealing with the universities will also be subcontracted. This phase of the work will start shortly and is expected to be completed by the end of this academic year. In this case, two basic questionnaires will be used: a long form for schools known to have done extensive work, and a short form for those with lesser interest in the subject.

AEC Contractors and AEC Employees Work Sponsored by Other Government Agencies

Parts three and four of the survey are concerned exclusively with government work and will be handled by AEC itself.

It is emphasized by Colmen that it will not be necessary to conduct such a survey every year. Once a "bench-

GAS-COOLED REACTOR

FACT: AEC is embarking on a gas-cooled reactor experiment (at National Reactor Testing Station in Idaho).

C.E.P. QUESTION: Does this imply a trend toward the British or "Calder Hall" type of full scale power reactor?

ANSWER: As told to C.E.P., January 18, 1957, by W. K. Davis, Director of Reactor Development, U. S. Atomic Energy Commission:

The Commission is most pleased with the success of the Calder Hall reactor," said Mr. Davis, "however, this had nothing to do with our decision to proceed with the design of the closed-cycle gas turbine reactor for which the AEC is presently negotiating a contract with the Aerojet-General Corp. of Azusa, Calif.

"Whereas the British reactors are large natural uranium reactors operating at moderate temperatures and pressures, our gas turbine reactor will use enriched uranium and will be designed for high gas pressures and extremely high temperatures. Problems of nuclear physics and of materials of construction will therefore be very different from those encountered in the British reactors.

mark" has been established by the present survey, the data can easily be kept up to date by statistical sampling techniques.

Comprehensive Scope

The questionnaire begins by asking for the number of scientists and engineers employed in nuclear energy activities as of September 30, 1956.

The total number is broken down into these functions: research and development; design and engineering; construction; operations, production and manufacturing; management and administration.

The manpower total is further cross-indexed by the type of activity in which each individual is engaged.

Main categories are: research reactors and allied facilities; power reactors and allied facilities; reactor components; reactor materials; nuclear fuels; radiation laboratory equipment and facilities; instrumentation; particle accelerators; by-product applications; and other.

Details on the educational level, specialized nuclear energy education, and practical experience of each scientist or engineer employed are asked for. Requests for estimates of the number of scientists and engineers which will be required by July 1, 1957, and a long-range guess as to the probable number which will be needed in 1960 wind up the questionnaire.

State of Emergency?

How important are the results of the present survey in the appraisal of our immediate nuclear educational needs? "By 1960-61," says J. F. Kaufmann, Chief of Technical Assistance Section, Division of Reactor Development, AEC, "we will need approximately 2,000 nuclear engineers per year at the Masters level. Since only about 4,000 Masters Degrees are now given annually in all fields, it is evident that drastic action is called for."

"It is expected that the Idaho reactor will be employed chiefly in the circulation of various gases through a variety of fuel elements for the purpose of testing materials and design factors at high temperatures and pressures."

There is in operation in France a gas-cooled reactor, Davis added, at Marcoule near Avignon. He said, however, that this reactor could not be considered economic since, while the total power output is 5,000 kw., 7,800 kw. are needed to drive the blowers.

The Swedes are understood to be building a gas turbine type reactor (in which heated gas is expanded through a turbine to recover part of its kinetic energy). Davis stated that this reactor will be rated at 40,000 kw.

NUCLEAR CONGRESS PROGRAM

(Continued from page 113)

mote Metallographic Equipment. J. R. Morgan, G.E. **The Techniques of Tensile Testing Irradiated Materials at Elevated Temperatures at Hanford.** W. S. Kelly, D. C. Kaulitz and R. E. Hueschen, G.E. **High Temperature Tensile Testing Facility at the Radioactive Materials Laboratory.** D. J. Ruggiero and R. F. Stearns, G.E. **Remote Operating Tukon Hardness Tester at Knolls Atomic Power Laboratory.** D. J. Ruggiero and R. F. Stearns, G.E. **Remotely Operable Bend Test Apparatus.** W. D. Valovage and G. L. Cutler, G.E. **Remote Welding of Stainless Steel Containers.** E. E. Pierce, Oak Ridge. **Booting Assembly for the Model 8 Master-Slave Manipulator.** R. B. Wehrle, Argonne. **Reactor Removal Shield and Carriage.** S. O. Lewis, Oak Ridge. **Low Power Stereo Camera.** W. B. Doe, Argonne. **SRE Fuel Decanner.** G. L. Torgison, North American Aviation. **Remote Operated Specimen Mounting Press and Conductive Mold Application.** A. J. Mattila, G.E. **A Hot Laboratory Facility for Remote Metallography.** D. D. LaRocque and F. P. Crimi, G.E. **Dismantling Equipment for Small Irradiation Bombs.** C. W. Angel, Oak Ridge.

EQUIPMENT FOR HOT CHEMICAL AND PHYSICAL OPERATIONS: Co-Chairmen: L. G. Stang, Jr., W. D. Tucker. **Special Equipment for Analytical Chemistry by Remote Control.** M. T. Kelley, D. J. Fischer and Staff, Oak Ridge. **Off-Gas Treatment in Berkeley Enclosures.** M. D. Thaxter, C. Burk and H. P. Cantelow, Univ. of Calif. **The Bettis Fission Gas Apparatus.** R. C. Kuch, J. E. Eck and F. S. Susko, Westinghouse. **A Liquid Sample Station.** T. L. Trent, Oak Ridge. **A Small Steel Shielded Isolation Box for Chemical Experiments.** R. P. Schuman and M. E. Jones, G.E. **High Level Solvent Extraction Facility.** K. H. Hammill and W. H. Adams, G.E. **A Facility for High Level Plutonium Solvent Extraction Studies.** R. S. Miller and D. J. Smith, G.E. **Equipment for Mechanical Dejacketing and Leaching of Spent Reactor Fuels in a Low Capacity Reprocessing Plant.** R. S. Miller and D. J. Smith, G.E. **Cobalt-60 Storage Garden and Irradiation Facility.** B. F. Early, Oak Ridge. **Design and Use of a 19,000 Curie Cobalt-60 Source for Materials Testing.** Marvin C. Atkins, Wright Air Develop. Center.

NAT'L. INDUS. CONFERENCE BD. 5TH ANN. ATOMIC ENERGY IN INDUSTRY CONFERENCE. PART 3: Commercial Power Reactors—Natural and Enriched Fuels. Advantages of various degrees of enrichment in terms of total net nuclear power costs. **Chemical Processing and Waste Disposal.** Problems in chemical processing and waste disposal methods and the techniques that are being developed to solve them. **Long-Range Outlook for Nuclear Industries.** Effects of atomic energy on major industries and the economy. **Safety and Health Problems.** The most recent data on radiation health and safety.

FRI., MARCH 15 (P.M.)

HOT LAB OPERATIONS AND ADMINISTRATION, GENERAL: Co-Chairmen: R. C. Westphal, K. Stratton. **A Survey of Remote Manipulation Equipment.** R. C. Goertz, Argonne. **Remote Manipulation Maintenance.** S. C. Smith, G.E. **Hot Laboratory Procedures at Argonne National Laboratories.** W. B. Doe, Argonne. **Hot Laboratory Functions in Nuclear Power Plant Operations.** S. L. Lindbeck, Westinghouse. **Hot Lab Organizations at Savannah River Laboratory.** W. J. Laird, Jr., DuPont. **Hot Cell Operation at the ORNL Solid State Division.** E. S. Schwartz, Oak Ridge. **Operational Problems in the Hot Lab Safety.** H.

W. Reynolds, H. K. Hunter, J. T. Conboy and W. H. Truran, G.E.

SPECIALIZED HOT OPERATIONS: Co-Chairmen: R. C. Goertz, K. R. Ferguson. **Techniques of Contamination Containment in Cave Operations.** G. J. Deily, DuPont. **The SRL Decontamination Facility.** J. W. Moffitt, DuPont. **Radiation Safety Monitoring of the Argonne National Laboratory's "Hot" Labs.** P. Tedeschi, Argonne. **Circulating In-Reactor Loops.** D. T. Jones, G. H. Jenks and H. C. Savage, Oak Ridge. **The Removal from the Brookhaven Reactor and the Sectioning of the In-Pile Unit of a Liquid Metal Fuel Reactor Loop.** C. J. Raseman, J. H. Klein and R. W. Stong, Brookhaven. **Experimental Facility for Multiple In-Pile Corrosion Tests.** T. L. Trent and A. F. Zulliger, Oak Ridge. **Hot Laboratory for Producing Synthetic Radioactive Fallout.** William B. Lance, U. S. Naval Radiological Defense Lab. **A Method for Irradiating Materials at High Temperatures in Co^{60} Sources.** Robert C. Weed and W. L. Kosiba, Brookhaven. **Semi-Remote Thermocouple Attachment: Operation and Resultant Hot Cell Decontamination.** F. E. Hancock and S. V. Castner, Convair. **Experiences with Disconnecting and Reconnecting Contaminated Systems.** M. D. Thaxter, Univ. of Calif. **Shielding Pot for Push Through Transfer of Radioactive Sources for Sealed Caves.** R. A. Blomgren, Argonne. **Push Through Shielded Filter Change Without Interrupting Exhaust.** R. A. Blomgren, Argonne. **Packaging of Fission Product Waste in a Remote Controlled Chemistry Cave.** C. H. Youngquist, Argonne.

HOT CELL INSTALLATIONS: Co-Chairmen: W. J. Laird, Jr., G. J. Deily. **Low Cost Manipulation of Millicurie Level Radioactive Materials.** M. B. Reynolds, G.E. **Shielding Calculations for Fission Product Gamma Sources.** W. G. Ruehle, G.E. **The Design of SRE Fuel Evaluation Hot Cells and Equipment.** J. M. Davis, North American Aviation. **A Multicurie Facility for High Level Chemical Process Research.** R. D. Fletcher and C. M. Slansky, Phillips Petroleum. **Semi Portable Steel Hot Cell.** C. C. Thomas, Jr. and C. C. Webster, Westinghouse. **Caves for High Level Gamma-Emitting Plutonium.** Raymond C. Goertz, Argonne. **Remote Handling Facilities at Chalk River, Ontario.** A. S. Bain, A.E. of Canada. **Remote Handling Considerations for Large Radioactive Cells.** R. L. Drexler, G.E. **Coloration of Shielding Window Glasses.** K. R. Ferguson, Argonne. **Manipulator Hot Cell.** H. M. Glen, Oak Ridge.

NAT'L. INDUS. CONFERENCE BD. 5TH ANN. ATOMIC ENERGY IN INDUSTRY CONFERENCE. PART 4: Atomic Energy Developments Abroad. Present and future roles of international cooperative programs.

Among the Hungarian refugees flocking into the country, a survey shows that many are "professional, technical and kindred workers." Vice President Nixon, in a recent report, states that more than 10% of those who arrived prior to December 31, 1956 had high professional or scholarly qualifications.

This pool of new talent, many of them engineers, should not be allowed to go to waste, and the National Academy of Sciences—National Research Council has established an office at Camp Kilmer, N. J. to help place these qualified people. All American industry and education is urged to consider the talents available and find out if they can use the refugees. □

NUCLEAR NEWS

NEW RADIATION LABORATORY

Goodyear opens its new radiation laboratory, first of its kind in the rubber industry, for the exploration and development of rubber products which will perform satisfactorily in a radiation environment.

Since rubber is particularly susceptible to radiation, Goodyear Tire and Rubber Co. has built its new $125,000 cobalt 60 installation to search for the most favorable compounding practices and chemical additives to improve radiation resistance. Other goals of the irradiation program will be to initiate chemical reactions, polymerization and vulcanization of rubber, and to improve physical properties of plastics and resins.

Choice of cobalt 60 was made because a wide variety of materials will be investigated, and the radiation field can be made effective over large samples. The cobalt 60 is in the form of small "slugs" or cylinders one inch long and one-eighth inch in diameter, sheathed in aluminum one-sixteenth inch thick. Nine such cylinders are assembled into an aluminum "pencil" about 10 inches long and there are 72 "pencils" in Goodyear's source. Activated in the NRX reactor at Chalk River, Ontario, by Atomic Energy of Canada, Ltd., (Canada's AEC), the Goodyear source has 2,100 curies of cobalt 60.

Extensive planning and preparation has been done for the handling of radioactive materials. Now ready for use, the cobalt 60 rests in a concrete and aluminum lined well which

Goodyear's cobalt 60 source in its well. The aluminum housing at upper left is where the cobalt 60 is raised during experiments so that a large number may be made at one time. Operator is checking radiation.

provides enough watershield for safe operation, inside a "cave" of thick, reinforced concrete.

Main feature of the installation: an elevator in the well which raises and lowers the source and makes it possible to enter the chamber at any time (when the source is under water), makes it possible to place samples anywhere in the chamber, eliminates the need for remote control equipment, and allows radiation to take place in air instead of under water.

A unique and unusual gamma irradiation facility, pictured here, has just been placed in operation by the Radioisotope Dept. of the Operations Division at Oak Ridge. Operated for AEC by Union Carbide Nuclear, this new facility is designed to utilize the radiation energy from Cobalt 60 slugs awaiting shipment to customers which would be lost under normal storage procedures. Since Cobalt 60 has a half-life of 5.3 years, the radiation field in the sub-surface storage installation from the 85,000 curies now stored has been measured at 1,100,000 roentgens per hour. Another feature of the unit is that samples can be irradiated in air rather than under water.

A new firm to be initially engaged in the melting of zirconium and its alloys, and the manufacture of certain zirconium mill products, has been formed by National Distillers and Mallory-Sharon Titanium Corp. Called Reactive Metals, Inc., the new company will have its plant built at Ashtabula, Ohio, site of National Distiller's new zirconium plant. □

Contract to engineer and construct the complete control system for the Curtiss-Wright Corporation Research Reactor (CWRR), has been awarded to Leeds & Northrup, Philadelphia instrument manufacturer. □

Newly-formed Nuclear Power Equipment Division of Kieley & Mueller, Inc., Middletown, N. Y., has been awarded $750,000 worth of valve contracts for special ultra-high temperature, bellows-sealed control valves complete with self-contained control systems for use in the nuclear powered propulsion field. □

OVERSEAS NEWS

RESEARCH REACTOR GOING TO JAPAN

First reactor to be sold directly by U. S. industry to a foreign country is now being shipped to Japan.

Intended for use by the Japan Atomic Energy Research Institute, the 50 kilowatt reactor, fueled with an aqueous solution of uranyl sulphate, was manufactured by Atomics International.

Issuance of a license by A.E.C. was based on the determination that it is within the scope and consistent with the bilateral agreement for cooperation between the Governments of the United States and Japan.

The Japan Atomic Energy Research Institute, formed in 1955 as a central organization for research and development and reorganized in June, 1956, into a special corporation, is supported both by the Japanese Government and private interests. It is concerned with basic studies in atomic energy, the collection of data on atomic power, the design, construction and operation of facilities, training of nuclear scientists and engineers, and the importation, distribution and use of radioisotopes.

While this will be the first reactor sold directly to a foreign country by U. S. industry, it is the second U. S. built reactor to go into operation abroad. The pool-type reactor designed and built at Oak Ridge National Laboratory and exhibited at the Geneva Conference was later sold to the Swiss Government for a Zurich research center.

Three additional applications for licenses to export research reactors are before the Commission. Two have been filed by AMF Atomics, Inc., New York, covering the export of a pool-type to Munich, Germany, and a light-water moderated type to be erected at an international exhibition in Amsterdam, Holland. The third application is ready to be issued a license for Babcock & Wilcox to export a pool-type to Brazil.

A contract for the construction of a 250 ton a day nitric acid plant to be built at Stanford-le-Hope on the Thames estuary in Great Britain for Fisons Limited, has been awarded to Chemical and Industrial International, Ltd. of Nassau, Bahamas. The plant was designed by the parent company, The Chemical and Industrial Corp., Cincinnati, Ohio. It is a single unit high pressure nitric plant and is the second of this type furnished by C & I recently in Europe. □

CHEMICAL ENGINEER GOES TO OLYMPICS

Newbold Black, chemical engineer of Houdry Process Corp., and a member of A.I.Ch.E., was one of the athletes to compete in the Olympic Games.

A.I.Ch.E. member Edgar Newbold Black, IV, carried the banner of chemical engineering as well as of the United States into Olympic Stadium, Melbourne, during the recent worldwide athletic contests. A member of the U. S. field hockey team (only the second field hockey team this country has sent since the 1932 Olympics), which he gained after exhaustive tryouts, Black has been an athlete since high school.

Chemical engineer Newbold Black (center) in action in field hockey game with U. S. Olympic team.

Graduate of the University of Pennsylvania, 1950, Black won varsity letters there, as well as at the Haverford School, and is quite a figure skating star on ice.

Reporting on his trip down-under, Black said that, "Without a doubt the most impressive sight of the Olympic Games was the opening ceremony." He found the Australians friendly and very hospitable, but technologically a good way behind the United States. Many products of U. S. industry that are standard items here are rarities down-under, such as central heating systems, washing machines and dishwashers, television, and frozen foods.

An agreement covering the sale of small nuclear power plants overseas has been announced by ALCO Products, Inc. Concluded with Humphreys and Glasgow, Ltd. of Great Britain, the agreement covers the sale of ALCO nuclear systems outside the North American continent. □

A 5000-kw nuclear reactor for Denmark will have its control system built by Leeds & Northrup Company. Prime contractor for the reactor is Foster Wheeler. □

A Boston Meeting Report

. . . how to train THE CHEMICAL SALES ENGINEER . . . formal or informal?

There is no shortcut to being a good sales engineer, recent panel * of experienced sales engineering experts decided. Experience plus training, hand in hand all the time, is best path to a successful career.

The only real question in the panel's mind was formal training vs. informal training. Panelist and Whiting Corp. vice president G. E. Seavoy asked the question, "Why formal training?" He answered it himself—"Because it pays!" It pays in reduced costs, speed, better sales, higher quality men, morale, and reduced supervision.

Experience is important. In the long run, Calvert Distillers' practical minded Kelly pointed out, "there is no substitute for experience."

But the important factor here is time. Henry Ford is credited with the observation, reported by Seavoy, "The school of experience is a great one, but its graduates are too old to work!" And formal training, Seavoy emphasized, is essentially a way of speeding-up the learning process.

J. J. O'Connell, of newly-formed Amoco Chemical, put it this way, "The sales engineer also learns by trial and error through experience in the field face to face with customers. This method has the advantage that it requires the minimum of assistance from others and the disadvantage that it is among the most imperfect. It certainly is the slowest in absolute time."

There is another reason for formal training. The graduate of the "school of hard knocks" has a tendency to be a first-rate engineer and even a first-rate salesman, but he also has a tendency to be narrow. MIT's Industrial Management School professor E. P. Brooks is convinced that "In the middle of the 20th Century, in order to be a 'whole man,' the engineer must not only understand his field, understand the humanistic elements in our culture, but must also understand the process by which economic life is organized under a private enterprise system." And this means, necessarily, formal training.

How to Train

"Formal training is a prescribed program of study and action which has been designed to fit a particular company's needs," Seavoy explained, and, "In informal training the new employee is generally shifted from department to department, largely as a result of expediency, and learns by the brush-off method." (Seavoy is not, however, speaking against job-rotation. Job-rotation, he feels, is a vital part of all formal training, but it must be planned and pertinent to the engineer's needs.)

To plan a formal training program the first step is to decide what sales engineers need to know. O'Connell lists five basic needs: 1) technical knowledge as engineers; 2) knowledge of company policy and attitudes; 3) knowledge of company products; 4) knowledge of the consuming industries, their applications, processes and buying habits; 5) knowledge of sales techniques.

The first of these is, O'Connell points out, the province of the college and university. The next three areas are definitely the responsibility of the employing company. Often these matters have been left to the hit-and-miss teaching of senior sales engineers while introducing the new man to his job. But today most companies take care of teaching policy and attitudes in formal orientation courses, and even tend to lean over backwards in teaching a knowledge of their products to such an extent, O'Connell feels, that they sometimes neglect the other phases of the sales engineer's education.

"Transmitting knowledge of consuming industries," O'Connell said, "is still in the formative area in most training programs." Until recently it was mainly passed on by word-of-mouth from experienced men, but this was unsatisfactory since sales engineers tend to be notoriously silent on this subject. Even today very few companies have formal training in this area and it is in need of considerable study, according to O'Connell.

The teaching of sales techniques ranges over all the stages of formality and completeness. The oldest, and still widely used, method is simple word-of-mouth, while "the more elaborate programs have intensive sales training in actual sales techniques by professional sales training groups." (O'Connell). In this area, company, college, and experience can all play an important part in the teaching process, and the special schools, such as MIT's School of Industrial Management, can add a great deal to the formal training of the sales engineer in a world where no one can really say just what the sales engineer may have to face or may need in his work. As Brooks said, "It is to create some understanding of the enterprise as a whole and hence the contributions which are made by capital, by sales, by production, etc."

The Advantages of Formal Training

Calvert's Kelly sounded the warning, "Selling is not an exact science. There is no shortcut to good sales." What Kelly was emphasing is that no training program can substitute for learning-by-doing, but it can be a great help. As Kelly said, it must go hand-in-hand with experience all through the sales engineer's career.

How formal training helps was again taken up by Seavoy. "The casualty rate (loss of trainee em-

(*Continued on page* 131)

* Symposium on Sales Engineering, Boston Annual Meeting of A.I.Ch.E., Dec. 9-12, 1956. Panel: W. E. Hesler, Swenson Evaporator Co., chmn.; L. C. Johnston, Benson-Funk, Inc., presiding; E. P. Brooks, MIT School of Industrial Management; G. E. Seavoy, Whiting Corp.; P. J. Kelly, Calvert Distillers; and J. J. O'Connell, Shell Chemical.

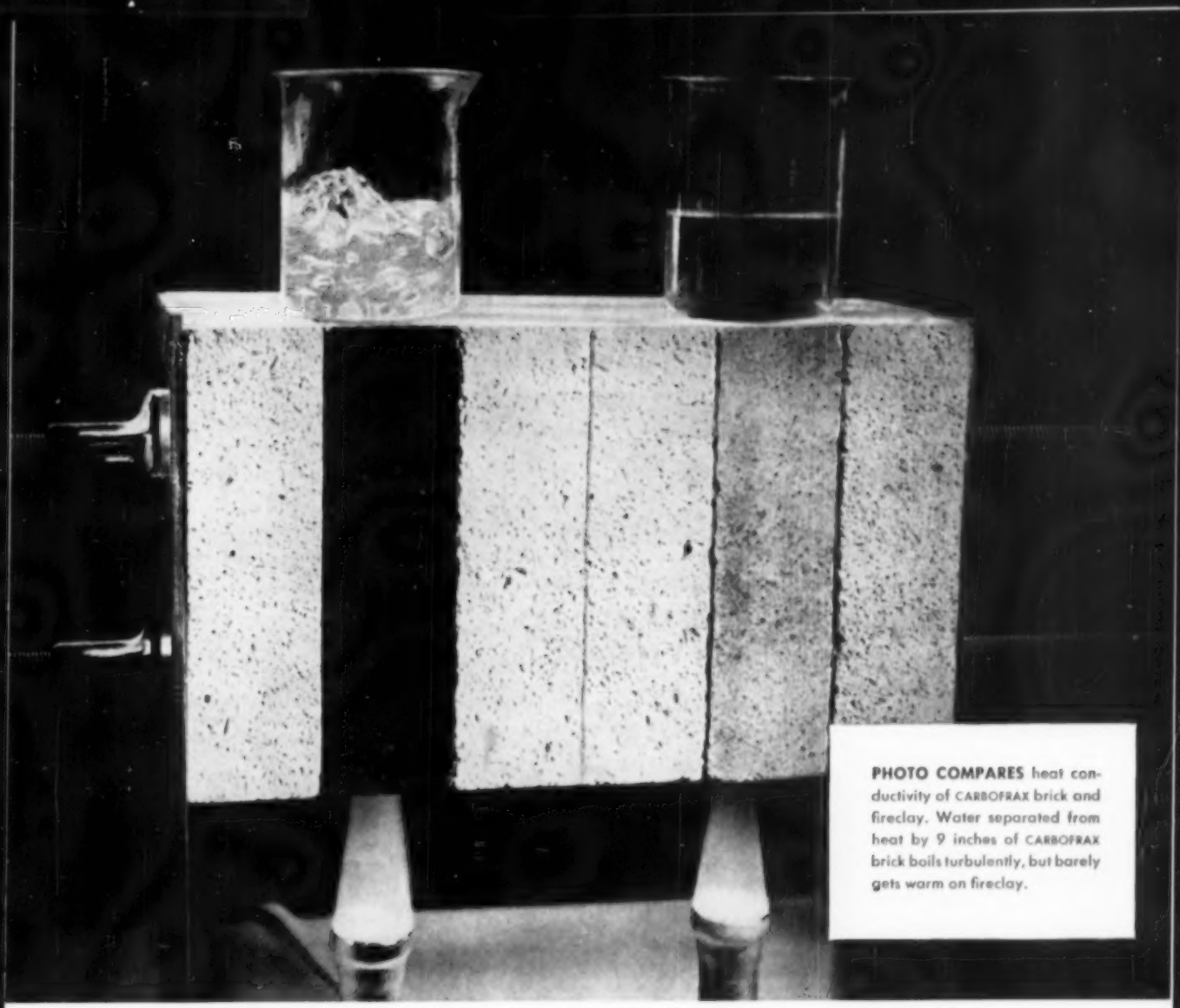

PHOTO COMPARES heat conductivity of CARBOFRAX brick and fireclay. Water separated from heat by 9 inches of CARBOFRAX brick boils turbulently, but barely gets warm on fireclay.

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FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

■ **WHITE SULPHUR SPRINGS, W. VA.**

March 3-6, 1957. Greenbrier Hotel.

For complete technical program see page 84 of January issue. Program highlights below. See also page 90 of this issue.

Computers in Chemical Company Control

The use of large-scale computers in handling payrolls, billing and ordering, sales forecasting, production control, etc.

Futures in the Chemical Industry

The future status of certain segments of the chemical industry and related areas, discussed from a 1965 viewpoint.

Scientists, Engineers & Management Decisions—A Problem in Teamwork

The psychological factors which must be considered to assure effective functioning of Operations Research (scientific decision-making) teams.

The Impact of Licensing on Chemical Engineering

Sunday afternoon panel discussion on professional registration.

Future Labor Trends in the Chemical Industry

Changes in the labor picture over the next ten years.

■ **PHILADELPHIA, PA.**

March 11 through 15, 1957.

EJC Second Nuclear Engineering and Science Congress & Exposition. (See page 80.)

■ **EVANSTON, ILL.**

April 8-10, 1957. Northwestern University.

Plant instrumentation symposium sponsored jointly by A.I.Ch.E. (Dave Boyd, Universal Oil Products Co., Des Plaines, Ill., chairman) and the Instruments & Regulators Div. of A.S.M.E. On the afternoon of April 9 there will be a session devoted to the dynamics of processes with Page Buckley, DuPont, presiding. Other sessions will be on application of automatic controls.

■ **ST. LOUIS**

June 3-7, 1957.

Golden Jubilee Meeting, Air Pollution Control Association; sponsoring societies include A.I.Ch.E. (Tuesday, June 4 will be A.I.Ch.E. day.)

Methods of Analysis; Instrumentation; Atmospheric Reactions, Photochemical & Other; Aerosol Formation & Control; Progress in Air Pollution Control Equipment & Methods; and Human & Economic Goals for Engineers in Air Pollution Control will be treated.

For information contact W. L. Faith, Managing Director, Air Pollution Foundation, 704 S. Spring St., Los Angeles 14, California.

(*Continued on page 126*)

FUTURE MEETINGS

(*Continued from page 124*)

MEETINGS **SYMPOSIA**

■ **SEATTLE, WASH.**

June 9-12, 1957. Olympic Hotel.

TECHNICAL PROGRAM CHAIRMAN: James G. Knudsen, Dept. of Chem. Eng., Oregon State College, Corvallis, Oregon.

Industry's Role in University Programs on Nuclear Engineering

CHAIRMAN: John Kaufmann, Div. of Reactor Development, U. S. Atomic Energy Commission, Wash., D. C.

Chemical Engineering Data and Calculation Methods

CHAIRMAN: W. C. Edmister, Calif. Research Corp., Richmond Laboratory, Richmond, Cal.

Filtration

CHAIRMAN: F. M. Tiller, University of Houston, Houston 4, Texas.

Electrochemical Engineering

CHAIRMAN: Joseph Schulein, Dept. of Chem. Eng., Oregon State College, Corvallis, Oregon.

Chemical Engineering in the Pulp and Paper Industry

CHAIRMAN: J. L. McCarthy, Dept. of Chem. Eng., Univ. of Washington, Seattle, Washington.

■ **PASADENA, CALIF.**

June 19-21, 1957. California Institute of Technology.

The 1957 Heat Transfer and Fluid Mechanics Institute. A.I.Ch.E. is one of the sponsoring societies. Papers on technical and scientific advances in fluid mechanics, heat transfer, thermodynamics, and related fields.

GENERAL CHAIRMAN: Peter P. Wegener, Jet Propulsion Laboratory, Calif. Inst. of Tech., 4800 Oak Grove Drive, Pasadena 3, Calif.

■ **STATE COLLEGE, PA.**

August 11-14, 1957. Pennsylvania State University.

First National Conference on Heat Transfer, featuring Applied Heat Transfer. Sponsors: A.I.Ch.E., A.S.M.E., & College of Eng. & Arch., Penn State Univ.

James N. Addoms, Atlas Powder Co., Wilmington 2, Delaware, is A.I.Ch.E. program chairman.

■ **BALTIMORE, MD.**

September 15-18, 1957. Lord Baltimore Hotel.

TECHNICAL PROGRAM CHAIRMAN: R. L. Copson, Mutual Chemical Co. of America, 1348 Block St., Baltimore 31, Maryland.

General Committee and operating committees have completed initial organization and are now functioning. Technical Program symposia will be decided on early in 1957. Approximately 14 plant trips have been suggested. Additional emphasis on student activities is one of the planned features.

The Alkali-Chlorine Industry

CHAIRMAN: Herman W. Zabel, Roger Williams, Inc., P. O. Box 426, Princeton, New Jersey.

Drying

CHAIRMAN: Ralph E. Peck, Chem. Engineering Dept., Ill. Inst. of Tech., Chicago 16, Ill.

Low Temperature Processing

CHAIRMAN: Clyde McKinley, Air Products, Inc., P. O. Box 538, Allentown, Pa.

MEETINGS **SYMPOSIA**

Direct Operating Labor Costs

CHAIRMAN: John Happel, Chem. Eng. Dept., New York University, University Heights, N. Y. 53.

ANNUAL—CHICAGO, ILL.

December 8-11, 1957. Conrad Hilton Hotel

TECHNICAL PROGRAM CHAIRMAN: Henry F. Nolting, Standard Oil Co., 2400 New York Ave., Whiting, Ind.

Fluidization of Solids

CHAIRMAN: E. R. Gilliland, Chem. Eng. Dept., M.I.T., 77 Massachusetts Ave., Cambridge 39, Mass.

Flow characteristics, rate of entrainment and heat transfer; fluidized reactors vs. fixed and moving bed reactors.

Effective Cost Control in Process Operations

CHAIRMAN: C. W. Nofsinger, The C. W. Nofsinger Co., 906 Grand Ave., Kansas City 6, Mo.

Evaluation of Projects from the Original Idea to the Investment Stage

CHAIRMAN: C. W. Nofsinger (see above).

Chemical Engineering Abroad

CHAIRMAN: Shelby Miller, Chem. Eng. Dept., University of Rochester, River Campus Station, Rochester 20, N. Y.

Corrosion Resistant Alloy Materials of Construction

CHAIRMAN: G. Fred Ours, Carbide and Carbon, Charleston, W. Va.

Laboratory and Pilot Plant Techniques

CHAIRMAN: G. W. Blum, The Goodyear Tire & Rubber Co., 1485 E. Archwood Ave., Akron 16, Ohio.

Radiation Processing

CHAIRMAN: J. J. Martin, Dept. of Chem. Eng., Univ. of Michigan, Ann Arbor, Michigan.

Nuclear Process-Heat and Radiation Source Reactor Systems for the Chemical and Metallurgical Industries

CHAIRMAN: B. W. Gamson, Borg-Warner Corporation, Des Plaines, Illinois.

Extractive Metallurgy

CHAIRMAN: B. W. Gamson (see address above).

Selling a Technical Program

CHAIRMAN: W. L. Bulkley, Standard Oil Company (Ind.), Whiting, Indiana.

Shock-Wave Concept of Equipment Design

CHAIRMAN: Stuart Churchill, Dept. of Chem. Eng., Univ. of Michigan, Ann Arbor, Michigan.

Use of Computers in the Chemical Industry

CHAIRMAN: Leon Cooper, Monsanto Chemical Company, St. Louis, Missouri.

Biological Processes

CHAIRMAN: Elmer Gaden, Dept. of Chem. Eng., Columbia University, New York City.

Separation of Chemicals from Paper Industry Wastes

CHAIRMAN: R. P. Whitney, Inst. of Paper Chemistry, Appleton, Wisconsin.

SALT LAKE CITY, UTAH

September 21-24, 1958.

TECHNICAL PROGRAM CHAIRMAN: E. B. Christiansen, Dept. of Chem. Eng., Bldg. 437, Univ. of Utah, Salt Lake City, Utah.

(Continued on page 128)

FUTURE MEETINGS

(Continued from page 127)

LOCAL SECTION MEETINGS

■ **PHILADELPHIA-WILMINGTON**

April 9, 1957. One-day meeting on "Catalysis in Practice" in conjunction with the University of Pennsylvania. Place: University Museum, Philadelphia.

Morning: Which Catalyst and Why?; Preparing an Industrial Catalyst; Fixed Bed Catalyst Systems; Moving Bed Catalyst Systems.

Afternoon: Economics of Catalyst Use; Operating Problems; Trends and Prospects.

Contact: L. R. Bechtel, Atlantic Refining Co., 2700 Passyunk Ave., Philadelphia 45, Pa.

UNSCHEDULED SYMPOSIA

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

- **Centrifugation:** James O. Maloney, Dept. of Chem. Eng., U. of Kansas, Lawrence, Kans. The theory and quantitative aspects of centrifugation.
- **Size Reduction:** Edgar L. Piret, Chem. Eng. Dept., U. of Minnesota, Minneapolis 14, Minn.
- **Filtration & Centrifugation:** Horace Hinds, Jr., Corn Products Refining Co., Box 345, Argo, Ill.
- **Chemical Engineering Process Dynamics as They Affect Automatic Control:** David M. Boyd, 315 Ridge Ave., Clarendon Hills, Ill.
- **Ethylene Manufacture:** Hermann C. Schutt, 201 Devonshire St., Boston 10, Mass.
- **Dry Classification of Solids:** D. W. Oakley, Metal & Thermit Corp., Carteret, N. J.
- **Saline Water Conversion:** W. L. Badger, 309 So. State Street, Ann Arbor, Michigan.
- **Statistics in Chemical Engineering:** John C. Whitwell, Princeton University, Princeton, N. J.
- **Education of Chemical Engineers:** F. M. Tiller, Dean of Eng., University of Houston, Cullen Blvd., Houston 4, Texas.
- **New Chemical Engineering Construction Techniques:** S. A. Guerrieri, The Lummus Co., 385 Madison Ave., N. Y. 17.
- **Mineral Process Engineering and Mineral Economics:** L. A. Roe, International Minerals & Chemical Corp., 20 North Wacker Drive, Chicago 6, Ill.
- **Foams and Froths:** J. L. York, Ramo-Wooldridge Corp., 8820 Bellanca Ave., Los Angeles, Calif.
- **The Threatened Imbalance Between Chlorine and Alkali in American Chemical Industry:** Zola G. Deutsch, Deutsch & Loonam, 70 E. 45th St., New York City 17.
- **Shock Waves in Process Equipment:** Chairman to be named.
- **Scale-Up Philosophy in the Chemical Industry:** Chairman to be named.
- **Start-Up of New Chemical Plants:** Chairman to be named.
- **Computers in Optimum Design of Process Equipment:** Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.
- **Kinetics & Rate Processes:** Neal R. Amundson, Institute of Technology, University of Minnesota, Minneapolis 14, Minn.

PROS AND CONS OF UNIONISM AT CHICAGO SECTION

One-day meeting of Chicago Section hears panel * discuss professional unionism. Union position—times have changed, engineer no longer a true part of management. Professional position—it is up to engineer to decide whether he wants to be truly professional or a highly skilled technical employee.

The spread of the "professional unionism" question to a major one-day local section meeting in Chicago underlines the growing importance of this issue to professional engineers.

Admitting that there is a tendency for engineers in the larger organizations to operate as highly skilled technical employees, GE's Langenwalter said, "It's up to us as engineers to make the choice now between being professionals or remaining highly skilled workers. In order to become a professional engineer, the engineers in industry must recognize that the profession requires recognition of responsibility to the public. . . . Each engineer in industry must look for the aspects of his job in which he recognizes responsibility to the public as a whole as well as looking over his responsibilities to his employer. . . . Only by showing that we as engineers are ready, willing and able to accept these responsibilities can we grow to be a profession."

Essence of unionists Ahmann and Stephens' positions was again that the engineer has problems, has not learned to deal effectively with group problems, must band together with other engineers in a union to achieve the salary, status, and professional recognition he should have. (See report on NICB Survey, and article by H. L. Rusch, in January, 1957, issue of *CEP*.)

Pro-professional panelist Wilson again emphasized that professional unions, no matter what their claims, must band together with trade unions to be effective, and eventually the professional concepts of responsibility to the public, to ethical standards, and

(Continued on page 132)

* B. Solomon, U. of Chicago, moderator; J. Ahmann, president of Engineers and Scientists of America; R. M. Stephens, president of American Federation of Technical Engineers (AFL-CIO); D. F. Langenwalter, General Electric; J. S. Wilson, Heidrick & Struggles.

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before March 15, 1957, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Blumberg, Sterling P., *Baytown, Tex.*
Bortolin, L. G., *Montreal, Que., Can.*
Boynton, Donald E., *Wilmington, Del.*
Brooks, John A., *Chicago, Ill.*
Christison, David, *Woodbury, N. J.*
Cier, Harry E., *Baytown, Tex.*
Cotabish, Harry N., *Pittsburgh, Pa.*
Domask, William G., *Baytown, Tex.*
Esser, Alvah E., Jr., *Torrance, Calif.*
First, Joseph J., *Chicago, Ill.*
Fritz, Don, *Memphis, Tenn.*
Gould, William H., *Cincinnati, Ohio*
Gray, L. R., *Martinez, Calif.*
Gunnerson, Hanford L., *Akron, Ohio*
Hammersley, R. Cameron, *Dunellen, N. J.*
Kaufman, John E., *Chicago, Ill.*
Kelso, William H., *Wilmington, Del.*
Lloyd, Robert D., *Homestead Park, Pa.*
Love, Robert M., *Baytown, Tex.*
Luke, Frederick T., *Glendale, Mo.*
Miller, Arthur J., *Ames, Iowa*
Nichols, G. Starr, *Augusta, Ga.*
Pansing, William F., *Whiting, Ind.*
Parkes, Augustus N., *Aiken, S. C.*
Patterson, Ralph G., *Wilmington, Del.*
Pennington, Edward N., *Bartlesville, Okla.*
Potash, Max, *Peabody, Mass.*
Pringle, John W., *Boulder, Colo.*
Smith, Richard D., *Avon Lake, Ohio*
Swandby, Earl R., *Waynesboro, Va.*
Thompson, F. E., *Whiting, Ind.*
Weinberger, Arthur J., *New Orleans, La.*
White, Niles C., *Huntsville, Ala.*
Wood, Frederick S., *Whiting, Ind.*
Woods, Allan, *Betteravia, Calif.*

Associate Member

Agnew, David F., *Houston, Tex.*
Andrews, Robert K., *Pensacola, Fla.*
Ballast, Donald E., *Midland, Mich.*
Baxley, Rufus A., Jr., *Charleston, W. Va.*
Berger, Max, *Pasadena, Calif.*
Black, Clifton L., *Salt Lake City, Utah*
Bonner, Edwin J., *Philadelphia, Pa.*
Boynton, H. G., *Baytown, Tex.*
Brennan, Earl D., *Verona, Pa.*
Bybell, Paul, *Wilmington, Del.*
Cabbage, William A., *Philadelphia, Tenn.*
Caylor, Gary C., *Charleston, W. Va.*
Cook, Ernest J., *Bay City, Mich.*
Dale, John M., *San Antonio, Tex.*
Daragan, W. R., *So. Charleston, W. Va.*
Denson, Costel D., *Ardmore, Pa.*
Dillow, William M., *Kansas City, Mo.*
Fan, Liang-Tseng, *Morgantown, W. Va.*
Farrow, A. Phil, Jr., *Knoxville, Tenn.*
Fisher, Gerald T., *Greenbrier, Tenn.*
Goode, James E., Jr., *Memphis, Tenn.*
Grover, Anson R., *Bloomfield, N. J.*
Hanna, Alfred E., *Port Hueneme, Calif.*
Herrington, Henry Charles, Jr., *Houston, Tex.*
Kessie, Robert W., *Brookfield, Ill.*
Kip, Charles E., *Portsmouth, Ohio*
Knowlton, Robert C., *Wilmington, Del.*
Kraft, Glen R., *Cleveland, Ohio*
Langley, Jesse Kenneth, *Lowland, Tenn.*
Leech, John G., *Westernport, Md.*
Louraine, Lewis E., *Texas City, Tex.*
Lyons, Frank H., Jr., *Memphis, Tenn.*
Mahl, Harry L., Jr., *Memphis, Tenn.*
Marchman, Lloyd F., *Aiken, S. C.*
Mazzone, Frank L., *Sistersville, W. Va.*
Montgomery, Joe Mac, *Baytown, Tex.*
Morris, James Ivey, Jr., *St. Albans, W. Va.*
Murrill, Paul W., *Pocahontas, Miss.*
Myers, Russell D., *Calhoun, Tenn.*
Nowlin, James F., Jr., *Houston, Tex.*
Oxley, Joseph H., *Columbus, Ohio*
Pardue, Ben T., *Sweetwater, Tenn.*
Patterson, John W., *Saginaw, Mich.*
Peper, Frederick H., *Fords, N. J.*
Petrosky, Regis D., *No. Braddock, Pa.*
Pfluger, Richard A., *Hoboken, N. J.*
Pint, James A., *Akron, Ohio*
Price, Thomas J., *Pittsburgh, Pa.*
Przybysz, Eugene S., *Chicago, Ill.*
Psyros, Hippocrates G., *So. Boston, Mass.*
Reitemeier, A. L., *Lafayette, Ind.*
Ritter, Jack F., *Wilmington, Del.*
Roberts, William E., Jr., *Charleston, W. Va.*

CANDIDATES

(Continued)

Saxton, Ronald L., *Yorklyn, Del.*
Schwellinger, J. D., *Beaumont, Tex.*
Scott, Harry S., Jr., *Kirkwood, Mo.*
Smith, Shea, III, *St. Louis, Mo.*
Somers, Allen E., *Pittsburgh, Pa.*
Staubach, Ernst J., *Foster, Ohio*
Stover, W. H., *Victoria, Tex.*
Straker, William R., Jr., *Chattanooga, Tenn.*
Take, Edward F., Jr., *St. Louis, Mo.*
Taylor, Rodney J., *St. Albans, W. Va.*
Von Rosenberg, Hermann E., *Baytown, Tex.*
Walker, Fred E., *Lowland, Tenn.*
Ward, David S., Jr., *Port Arthur, Tex.*
Ward, James F., Jr., *No. Augusta, S. C.*
Watts, Charley D., *Pittsburgh, Pa.*
Whitney, Erwin C., *Corpus Christi, Tex.*
Young, Kin-Ching, *Knoxville, Tenn.*

Affiliate

Adams, Charles A., *Gulf Breeze, Fla.*
Dezmelyk, Eugene W., *Drexel Hill, Pa.*
Gordon, William O., *Atlanta, Ga.*
Hewitt, William R., *Cleveland, Ohio*
Wahrmund, Robert C., *Baytown, Tex.*

THE CHEMICAL SALES ENGINEER

(Continued from page 122)

ployees) is widely divergent with formal versus informal training. The extremes are in order of magnitude of 10% with formal training and 80% with informal."

But the pay-off is far richer in other respects. A salesman *is* his company in the eyes of the customer. If he is not trained in all 5 areas outlined by O'Connell, as well as having the formal training in the broad areas of business urged by Brooks and being instituted in many engineering schools these days, he is not going to be an effective representative of his company until he has had long experience which cannot be waited for today without losing much efficiency. With that general set of ideas, Seavoy went on to list the main tangible advantages of formal training:

1) It is much less expensive in total net dollars than costly, unpredictable hit-and-miss methods.

2) It is faster in achieving the goal —sales results.

3) It tends to develop higher quality men.

4) It helps solve the technical manpower shortage by achieving better productivity more quickly.

5) It implements advancement through upgrading and therefore improves morale.

6) It shows almost immediate evidence of improved customer relations.

7) It reduces managerial control since trained men need less general supervision.

A.I.Ch.E. News of the Field — FROM LOCAL SECTIONS

(*Continued from page 129*)

to their fellow engineers, will be lost.

Reporting on a recent GE survey of the professional union situation, Langenwalter pointed out that the union represented by Stephens has few if any engineers as we know them, but that Ahmann's ESA, in its affiliated unions, does have a majority of true engineers. Again echoing the NICB report and the Rusch article, Langenwalter emphasized that most ESA members are in the large companies which employ engineers *en masse*, showing that management must accept considerable responsibility for treating the engineer as a professional if the engineer is to achieve that status universally.

COMPUTERS, MANAGEMENT AND LEADERSHIP, SALES, HOLD FLOOR AT LOCAL SECTION MEETINGS

In asking the question What Good are Computers to Engineers?, J. J. Stone, chief of systems engineering research at Battelle Memorial Institute, answered his own question, went into whole history of computing devices before the November meeting of the **Central Ohio Section** (*W. W. Ellis*). In order for computers to be of use to engineers, Stone explained, the first requirement is that the problem be defined and the limits of the study be set. Then the known and unknown factors must be identified and assumptions must be determinded where possible. Next a flow diagram must be established and transferred into codes. After this the problem may be run on the machine, and the results interpreted. In reviewing just what a computer is, Stone listed the evolution of computing machines: 1) slide rule; 2) adding machine; 3) automatic number input to adding machine; 4) desk calculator; 5) automatic input and fixed sequence operations; 6) automatic input and selected sequence operations; 7) automatic input of instructions and numbers with the resulting addition of branch constructions and the modern digital computer. Comparing the analogue to the digital computer, Stone showed that the analogue gives an approximate, not an exact, answer as the digital does. The digital computer is particularly useful in solving problems of heat flow, network analysis, nuclear computations, and many engineering design studies.

Management—Leadership

When an engineer enters management he changes his profession! This was the essence of the talk of Moorehead Wright, General Electric, to the December meeting of the **New York Section.** Both the engineer and his company should remember this fact when considering an engineer for a top management position. It is time, Wright said, that we all recognized that management is becoming a profession in itself, that it takes a special type of person and training, and that there must be more than one path to the top, i.e. a good engineer must have the opportunity to reach the top *as an engineer*, as well as by the management route. Too often, Wright emphasized, an engineer is "rewarded" by being sent to management where he is out of place and miserable. This is a waste for both the man and the company. Many engineers do make excellent leaders and managers, but not all, and they must find that they can achieve as much as engineers.

Turning to creativity and leadership, F. Massarik, U.C.L.A. School of Business Management, emphasized to the December meeting of the **Southern California Section** (*R. D. Sheeline*) that there is no known formula, plan or program that will induce creativity. In fact, we know practically nothing about true creativity, and there are probably as many ways to be creative as there are people. Leadership toward creative work, however, can be planned. The first step is to find people with demonstrated creative resources and get them together and let them work. But the most important step is to create the proper "climate" for creativity. "Afraid of the boss," or "we've always done it this way," climates stultify creativity. Creativity is indigenous to the climate of openness, freedom of thought, and recognition that there are many solutions to any given problem.

Engineer Esteem

A disturbing report on the Washington Educational Association's public opinion survey, which indicated that engineers are generally held in low esteem with respect to the other professions, was reported by R. Florine to the October meeting of the **Washington-Oregon Section** (*J. B. Heitman*). Florine added that the place to change this opinion was among the students, and during the discussion names of prospective speakers for high schools were obtained.

Polymers are basically divided into two types—condensation and ethylenic

(*Continued on page* 134)

News of the Field

FROM LOCAL SECTIONS

(*Continued from page* 133)

—explained J. M. DeBell, DeBell and Richardson, Inc., to the October meeting of the **Oklahoma Section** (*L. A. Warzell*). Condensation polymers were originated from work with glycerol and phthalic anhydride. Ethylenic polymers have achieved new properties through special physical effects such as orientation. Special fabrication, forming, and molding techniques have done much to expand the sale of plastics. Oriented films give desirable properties for many applications.

Also Meeting . . .

El Dorado Section (*D. S. Thomas*), in November, heard F. J. Curtis, Monsanto v.p., discuss the importance of the distaff side of the engineer's life. Very important, said Curtis, can make or break a man's career. . . Also in November, **New Jersey Section** (*W. E. Deyerle*) was host to now ex-president Walt Whitman, who spoke again on his Geneva Conference experiences. . . Interesting youth in technical education was the subject of C. A. Read, General Electric, at the December meeting of the **Atlanta Section** (*N. R. Maleady*). Read discussed various programs of General Electric designed to interest high school students. . . **Rhode Island Section** (*J. L. Campanella*) in December heard H. A. Faber, Office of Engineering Services, give a statistical evaluation of our water resources and requirements, refinements and recovery. He also discussed how engineers must find ways to recover water from polluted sources. . . **Maryland Section** (*S. C. Streep*) held its annual business meeting in December and heard a talk, with films from Esso, on Flowing Solids and Refinery in Miniature. . . 80 members of the **Detroit Section** (*R. D. Stevenson*) saw the J. Arthur Rank produced movie Atomic Physics at the section's December meeting. The movie, obtained through National A.I.Ch.E., depicted the development of atomic energy from Faraday to the present. . . **Central Virginia Section** (*E. R. Swandby*) heard H. E. Atkinson, Du Pont, tell of new developments in plastics applicable to the chemical industry, some not yet commercial, some expanded uses for such established plastics as PVC and polyethylene. . . **Texas Panhandle Section** (*C. M. Oktay*) held a panel discussion on Professional Career Opportunities in Industry at its December meeting.

people

Thomas H. Pigford, associate professor of nuclear and chemical engineering at M.I.T., will join General Dynamics Corp.'s General Atomic Division as chairman of its John Jay Hopkins Laboratory for Pure and Applied Science. Dr. Pigford is co-author with Manson Benedict of the paper on "Fuel Cycles in Single-region Thermal Reactors" (see page 96-F of this issue) which will be presented at the 1957 Nuclear Engineering and Science Congress in Philadelphia (March 11-15).

Pigford

James Dustin promoted to position of superintendent of the materials and methods department, A. E. Staley Manufacturing Co., Decatur, Ill.

Richard D. Hook of Mellon Institute is elected vice chairman of the National Technical Task Committee on Industrial Waste.

Trimbey Machines, Inc., Glens Falls, N. Y., announces appointment of **D. J. Morrissey** as chief engineer.

Stevens

Babcock & Wilcox names **William D. Stevens** as Engineering Department coordinator in their New York offices.

The Pfaudler Co. announces appointment of **Ernest W. Neben,** formerly assistant chief engineer, as director of central engineering and of **Joseph M. Culotta** as chief project engineer.

William S. Landers named chief of the Branch of Coal Technology for Region III, Bureau of Mines.

Dunn

Blaw-Knox Co., Pittsburgh, Pa., announces appointment of **W. Earl Dunn** as vice president and general manager of its Chemical Plants Division.

Roy C. Newton, vice-president of Swift and Company, Chicago, Ill., selected to receive 1957 gold medal of the American Institute of Chemists in recognition of his leadership in food technology.

(*Continued on page* 136)

people


Pitzer

Bakelite Company names **G. L. Pitzer** as vice-president—production. Mr. Pitzer has been with Union Carbide and Carbon since 1933.

William A. Pardee, Gulf Research and Development Co., Pittsburgh, Pa., is awarded Scroll of Honor of ACS's Division of Industrial and Engineering Chemistry.

J. Lee Marsh named vice-president for development at Carbide and Carbon Chemicals Co. Dr. Marsh will be responsible for the development department of the Chemicals Co. as well as for all phases of its textile fibers activities.


Ekholm

Wesley C. Ekholm promoted to newly-created post of General Manager of Manufacturing for Columbian Carbon Company's Carbon Black Pigment Division.

Texas Company announces appointment of **R. J. Ronan** as regional manager of technical services. Ronan's territory will include 14 eastern and middle-Atlantic states.

Dean S. S. Steinberg, Univ. of Maryland College of Engineering, resigns to become president of the Technological Institute of Aeronautics at Sao Jose dos Campos, Sao Paulo, Brazil.

Edward H. Perkins, Jr., named to post of vice-president of Brooks & Perkins, Inc. Before his association with B. & P., Perkins was sales engineer with Aluminum Co. of America.

Calkin & Bayley, newly-organized industrial consulting firm, is now located at 50 East 41st St., N.Y., N.Y. Officers of the new corporation are **John B. Calkin,** president; **George T. Bayley,** executive vice-president; **Robert Frank,** vice-president in charge of marketing and economic research; and **John L. Parsons,** vice-president in charge of pulp and paper.


Calkin

W. M. Leaders made technical director of Mallinckrodt Chemical Works' Special Metals Division.

Barrett Division, Allied Chemical & Dye, announces retirement of **C. G. Stupp,** vice-president. Mr. Stupp had been with Barrett for forty years.

Chemical Construction Corp. appoints **W. J. Rosenbloom** as director of engineering.

C. Harold Fisher, chief of the United States Department of Agriculture's Southern Utilization Research Branch, New Orleans, has won the 1956 Southern Chemist Award of the American Chemical Society's Memphis (Tenn.) Section.

Charles H. Riesz, authority in the field of catalysis, promoted to senior scientist at Armour Research Foundation of Illinois Institute of Technology, Chicago.

Henry L. Cox resigns as vice-president of Corn Products Refining Co. to engage in private practice as technical consultant in chemistry and chemical engineering.

Monsanto appoints **Franklin D. Smith** as manager of university development in the company's general development department. Mr. Smith will be responsible for scientific liaison with universities and colleges.

Fred Torn is named head of the new Plant Engineering Section at the Los Angeles plant of American Potash & Chemical Corp.

Du Pont announces that **Charles B. Livingston** has joined their Engineering Department as field engineer in the research division of the Organic Chemicals Dept. Mr. Livingston comes to Du Pont after having been connected with Monsanto and the Army Chemical Corps.

Robert H. Moen joins staff of Esso Research and Engineering Company's petroleum development division at Linden, N. J.

Koppers Co. announces appointment of **H. A. Kjellman, Jr.,** as superintendent of their new development plant at Arroyo, W. Va.

Percy E. Landolt is elected to the board of directors and made vice-president of Basic Atomics, Inc. Mr. Landolt has been associated with the development of the lithium industry for thirty years and was one of the founders of the Lithium Corp. of America.

Du Pont announces appointment of **Arthur M. Friedman** to the research staff of their Jackson laboratory.

James O. Brown, plant manager, Petro-Tex Chemical Corp., Houston, Texas, since 1955, has been elected a vice-president.

E. Archer Turner, formerly president and director of Read Standard Corp., New York, joins Baker Perkins, Inc., as director, member of the management committee and vice-president.

O. C. Baker becomes manager of the Industrial Division of Infilco, Inc.

Olin Mathieson Chemicals Corp. names **Kenneth L. Weeks, Jr.,** as superintendent of their new chlorine and caustic soda operations at Brunswick, Georgia, plant to be completed shortly after the first of the year.

A. S. Gilliam becomes plant manager of Great Northern Oil Co.'s Pine Bend, Minn., refinery.

Wyman L. Taylor promoted to administrative assistant to the vice-president, Pacific Coast, of Stauffer Chemical Co. Mr. Taylor joined Stauffer in 1946.

(*Continued on page* 138)

people

New director of organization planning at Mead Johnson & Company is **S. W. Kapranos.**

Clarence L. A. Wynd, with Eastman Kodak Co. since 1927, has been elected vice-president.

George E. Symons, consultant and technical editor, leaves private practice to become executive vice-president and editorial director of Scranton Publishing Co., Inc., of New York and Chicago.

Pittsburgh Section of the American Ceramic Society chooses **Francis C. Flint,** technical director of the Hazel-Atlas Glass Division of Continental Can, to receive the 1957 Albert Victor Bleininger Award for achievement in ceramics.

Donald H. Tilson named manager of Aluminum Co. of America's Northwest operations. Mr. Tilson, with Alcoa since 1920, will assume overall responsibility for Alcoa's smelting and fabricating operations at Vancouver and Wenatchee, Wash.


Dougherty

Dwight A. Dougherty appointed general manager of SD Plants, Inc., construction subsidiary of Scientific Design Co. Mr. Dougherty was formerly with M. W. Kellogg.

Thorndike Saville retires after 20 years' service as dean of the New York University College of Engineering. Dr. Saville has long been recognized as a leader not only in engineering education but also in the development of the profession itself. He was instrumental in the current decision to make a comprehensive survey of the engineering profession in the United States.

Pennsalt Chemical names **Hugh C. Land** as general manager of the new Industrial Division.

Pabst Brewing Company names **Thomas H. Vaughn** executive vice-president in charge of corporate development.


Vaughn

New vice-president of Infilco, Inc., is **E. G. Kominek.** Mr. Kominek has made many technical contributions in the fields of water and waste treatment.

Charles Fox appointed project engineer on the Martin nuclear-powered electrical generating system which Martin's Nuclear Division is building for the Dominican Republic.

Merck & Co. announces appointment of **William W. Brown** to the newly-created post of director of operational services in their Merck Sharp & Dohme International Division.

Leon R. Chrzan appointed to staff of Tonawanda, New York, laboratories of Linde Air Products Co. Mr. Chrzan was previously associated with the Detroit research laboratories of the Ethyl Corp.

E. F. Koenig becomes technical representative of the technical services division of The Texas Company's research and technical department. He will specialize in additives for petroleum lubricants.

Monsanto Chemical Co. announces appointment of **Joseph P. Berndt, Jr.**, as assistant manager of the project engineering section in the engineering department of their Inorganic Chemicals Division.

Arthur A. Moore, formerly assistant manager of the Research Administration Section, is appointed Manager of the business services section, Research Department, Koppers Co., Verona, Pa.

New assistant general manager of manufacturing at Esso Standard Oil Co. is **Fred A. L. Holloway.** Mr. Holloway was previously general manager of the East Coast division of Esso's Manufacturing Department.

Holloway

Ezekail L. Clark, previously director of pilot-plant and petrochemical laboratories for Israel Mining & Industries, announces opening of chemical engineering consulting offices at 6551 Dalzell Place, Pittsburgh 17, Pa.

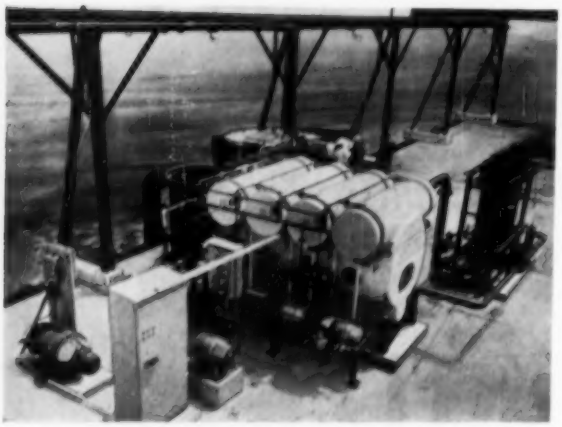
Johan E. A. Graae joins Chemical Engineering Division of Argonne National Laboratory as associate mechanical engineer. For the past 13 years Mr. Graae has been with Lummus Co. as senior engineer associate.

General Mills transfers **Robert Shreve** from the O-Cel-O Division to their research laboratory in Minneapolis, Minn. He will be a section leader in the Chemical Engineering Department.

(Continued on page 152)

CEP CAMERA

SEA WATER DISTILLATION



Under test at International Nickel's Kure Beach test site on the Atlantic Ocean, Badger Manufacturing Co.'s 1,000 gal./hr. four-stage flash-type sea water evaporator. Portable, can be shipped as unit to industrial plants, can use flare gas for heat.

BOSTON TALLY

Firms well-represented (8 or more attendees) at Boston Annual Meeting:

Atlantic Ref.	10	Gen. Foods	17
Amer. Cyan.	29	Humble	14
Air Products	15	Houdry	11
Allied	9	Kellogg	15
Badger Mfg.	30	Koppers	11
Col. Southern	16	Little, A. D.	32
Cabot	13	Lummus	9
Carbide	34	Linde	18
DuPont	82	Monsanto	75
Dorr-Oliver	13	Merck	15
Diamond Alk.	13	Olin-Math.	12
Dow	39	Std. Oil (Ind.)	26
Dewey-Almy	17	Sun Oil	12
Ethyl	12	Socony Mobil	8
Esso R&E	14	Stone-Websf.	25
Goodrich	11	U. Carb. Nucl.	12
G-E	20	Wyandotte	9

WANT TO OWN YOUR OWN BUSINESS?

Panel (at Boston A.I.Ch.E. annual meeting, Dec. 9, 1956) cited freedom to translate ideas into action with only oneself as buffer, plus lure of capital gain, as principal drives. Intelligent young people possessed with innate unwillingness to accept discipline often achieve success "on own." The price is high, however. Five to ten years of skimping, 16-hour days, adequate capital, are some of requirements.

WHO'S WHO in Nuclear Engineering Division

1957 officers for N.E.D. are pictured below. Rodger, as new member of Executive Committee, will serve for three years; others are (two years) J. A. Lane, (one year) M. C. Leverett and J. W. Clegg. Chairman Herb Isbin is pictured (left) at site of University of Minnesota's new gamma irradiation facility, which he is administering. Camera view is looking down into 16 ft. deep water well, used to store 1,000-curie cobalt-60 source.

NEW OFFICERS A.I.Ch.E. NUCLEAR ENGINEERING DIVISION

H. S. Isbin
Chairman

W. K. Davis
Vice-chairman

C. E. Dryden
Sec'y-Treas.

W. A. Rodger

M. C. Leverett

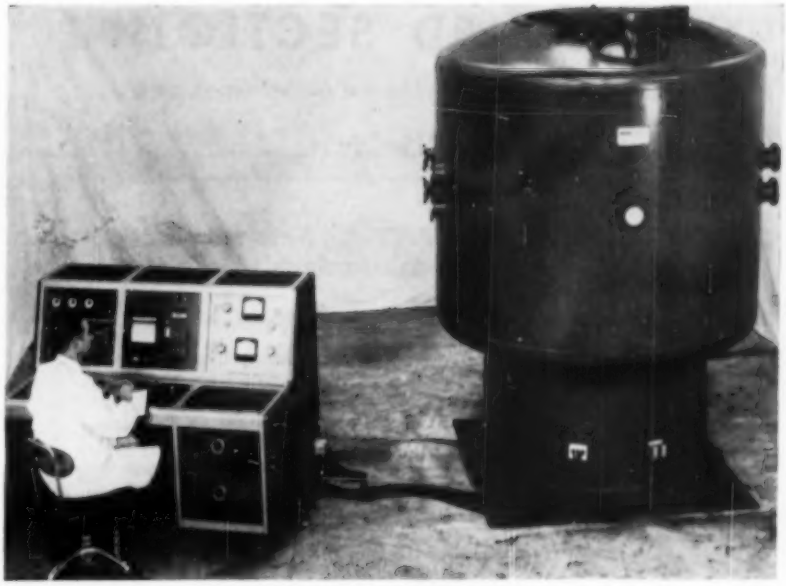
J. A. Lane

J. N. Clegg

Executive Committee

ATOMIC REACTOR TO OPERATE AT PHILADELPHIA ATOMIC EXPOSITION

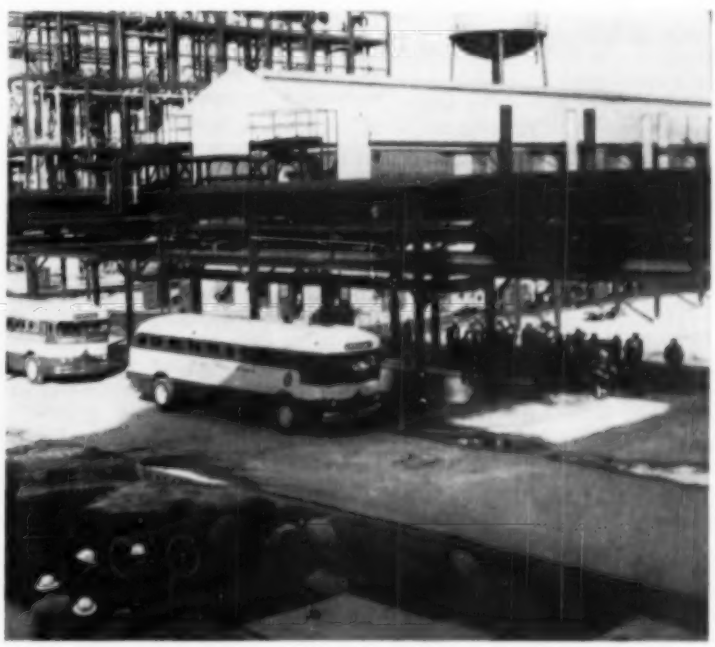
First public showing in U. S. of a nuclear reactor in operation will take place at Atomic Exposition, Philadelphia, March 11-15. Unit will be Aerojet-General Nucleonics' "Aerojet," the first mass-produced reactor. Under extensive consideration for use in training programs and research, the reactor will be operated at a low power of 100 milliwatts. AGN will demonstrate reactor operation several times each day. Engineers will be available to discuss applications.



STUDENT chemical engineers were provided with important day-long program at Boston Annual Meeting. Left: Panel on "keeping abreast of the chemical industry"; McAfee, Silcox, Wilhelm, Nichols, Cooper. Right: Michaels (co-chmn. student meeting); Gene Hopkins, student delegate from chapter at Texas A&M; Charles May, same from Iowa State; Eames (co-chmn.). Student chapters paid delegates' expenses.

CARBIDE & CARBON TEXAS CITY PLANT VISITED BY CHEMICAL ENGINEERS

South Texas Section of A.I.Ch.E. was recently honored by being the first outside group to tour (on January 18) the vast Carbide & Carbon Chemicals Co. Texas City petrochemical works. View shows two of the buses, with visitors in separated groups. Tour encompassed No. 1 compressor building, acetaldehyde unit, and power house.



BURT HONORED

Wm. I. Burt, past-president of A.I.Ch.E. and president of Goodrich-Gulf Chemicals, Inc., congratulated by J. L. Collyer (left) and W. S. Richardson (right) chairman and president of B. F. Goodrich, respectively, as they present him with watch for 30 years' service.

CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

SITUATIONS OPEN

CALLERY CHEMICAL COMPANY . . . . pioneer in HIGH ENERGY FUELS has openings for:

CHEMISTS—research in organic, inorganic, analytical, physical.

ENGINEERS—process design and economic evaluations, project engineering, plant construction and operation, safety.

B.S.—M.S.—PhD. **1-10 years' experience**

Permanent positions in association with recognized experts in this expanding new field. All benefits. Headquarters 30 miles north of Pittsburgh.

Send résumé to:

Personnel Manager

Callery Chemical Company

Callery, Pennsylvania

CHEMICAL ENGINEERS

American Viscose Corporation, a chemical-process industry, has some **permanent** positions open now for **chemical engineers.** To qualify you need a B.S. or M.S. **degree** from a recognized institution, and, preferably, 3-5 years of experience in process development, product-improvement studies, or chemical engineering 'trouble-shooting' for manufacturing.

The location is in suburban Philadelphia (Marcus Hook) at the **Research and Development Division,** or at one of our seven plants in Pennsylvania, West Virginia, and Virginia.

AVISCO

These openings are technically challenging and offer good advancement opportunities. Interested candidates are invited to submit résumés of personal data, educational history, and work experience to:

Personnel Recruitment Department

AMERICAN VISCOSE CORPORATION
1617 Pennsylvania Boulevard
Philadelphia 3, Pennsylvania

ENGINEERS

Chemical
Mechanical
Petroleum

Assignments in our Chemical Engineering Department cover application of processes to a wide variety of industrial plants, complete integrated refineries and chemical processing centers. The work includes coordinating of chemical engineering, selection and design of process equipment and startup of completed plants. Send a summary of your experience and interests to F B Stratford, Head of Personnel, C F BRAUN & CO, Alhambra, California.

CHEMICAL ENGINEER

Permanent position with basic chemical plant; small town location near St. Louis, Missouri. To work about one year on plant processing and control problems; thence to start a Technical Sales Service Department. Prefer recent graduate with 1-4 years' experience. Please submit in confidence detailed personal history, experience resume, recent photograph (if available), and salary requirement. **Box 18-2.**

ESSO ENGINEERING EXPANSION NEEDS

Chemical engineer needed for expanding plant scale research program on newly developed petroleum and petrochemical process equipment.

Work involves establishing incentives for commercial tests, planning program, directing test work in the field, and interpreting significance of data obtained. Frequent travel to different refinery locations.

Job requires sound knowledge of chemical engineering principles and ability to deal with practical plant problems. Prefer man with one to five years experience.

Give full details of education, experience, desired salary, availability date and references. All inquiries will be considered promptly and held confidential.

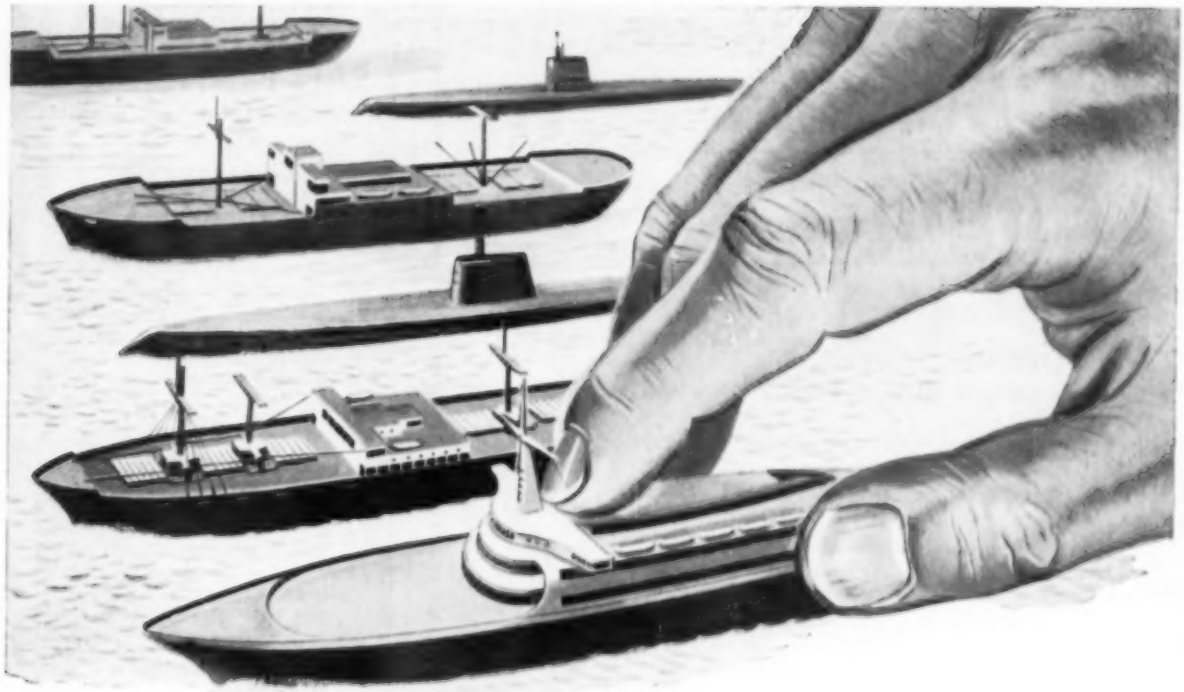
ESSO RESEARCH AND ENGINEERING COMPANY

(Chief Technical Subsidiary-Standard Oil Company (New Jersey))

Esso Research Center
Employee Relations-C

P. O. Box 51 **Linden, N. J.**

METALLURGICAL ENGINEERS...



Help develop the world's first nuclear powered fleet

The U.S.S. *Nautilus*, the first outstanding application of nuclear power to naval vessels, has demonstrated the potentialities for a modern, streamlined fleet which could cruise at high speed without the restrictions of frequent refueling. As the pioneer in nuclear power, the Westinghouse Bettis Plant in Pittsburgh is playing a leading role in producing power reactors for this nuclear fleet. Not only are Bettis engineers now developing more advanced reactors for submarines, but they are also pioneering nuclear reactors for a guided missile light cruiser and an atomic aircraft carrier.

Much of the technology used to harness the atom for nuclear propulsion is being developed for the first time. Our growth to date must be continued by creative engineers who enjoy the challenge of new technological advancement.

METALLURGICAL ENGINEERS are needed to develop the materials and processes for the manufacture of atomic cores, the heart of the nuclear power plant. The metallurgist is responsible for the development of uranium alloys together with cladding alloys to form a composite fuel element consistent with the reactor core requirements. He must also solve the major metallurgical processing problems that will arise in the pilot manufacturing of these elements.

CORROSION ENGINEERS provide consultation service on problems of high temperature, high purity water as well as planning and evaluating testing programs designed to determine suitability of materials used in applications where crevice, fretting stress and corrosion fatigue present difficult materials problems. Regardless of your interest, you will be able to choose a position in our varied operations. Atomic experience is not prerequisite!

Located in Pittsburgh's South Hills, Bettis Plant is adjacent to pleasant suburban areas as well as convenient to one of the nation's most progressive cities where educational opportunities are exceptional.

If you are interested in working in the field of atomic power write for the brochure, "Tomorrow's Opportunity Today." Address Mr. A. M. Johnston, Westinghouse Bettis Plant, Dept. A-122, P.O. Box 1468, Pittsburgh 30, Pennsylvania.

BETTIS PLANT

Westinghouse

Chemical Engineers

The Glenn L. Martin Company

has a separate NUCLEAR DIVISION which is engaged

in the development and manufacture of

PACKAGED REACTORS,

SMALL COMMERCIAL POWER STATIONS,

and SPECIAL APPLICATIONS FOR THE A. E. C.

Openings exist for:

1. Chemist or Chemical Engineer — B.S. degree, approximately 2 years experience in Research and Development work, no Nuclear experience required.
2. Organic Polymer Chemist — M.S. degree, approximately 2 years experience in Syntheses and Tailor-Made Monomers for work involving study of Polymerization Radiation stability.
3. Solid State Phyicist — Inorganic Chemist, Ph. D. or M.S. degree, for fundamental studies of interactions of radiation with metals.
4. Radio Chemist—M.S. degree, experience in fundamental Radio Chemical Studies.
5. Chemical Engineer—B.S. degree, for heat transfer Analysis work.
6. Positions available at all levels for Chemical Engineers and Physicists—with or without experience.

Please contact our representative, Mr. Chuck North, at the Ben Franklin Hotel, Philadelphia, during the Atomic Exposition, March 11 through 15, or

Professional Employment Office

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NEW YORK OR SAN FRANCISCO

BECHTEL

Offers immediate long range opportunities for

ENGINEERS

CHEMICAL - MECHANICAL

Process or project experience in refinery, petrochemical or chemical fields.

Liberal relocation allowances for you and your family.

Send resume to

Manager of Employment & Placement
Industrial Relations Division

BECHTEL

Engineers and Builders for Industry

220 Bush St. San Francisco 4, Calif.

For an immediate personal interview you may phone:

Paul Keating, Murray Hill 7-7100, New York City
Joe Braddick, Fairfax 3-2401, Houston, Texas
Bill Milligan, Tucker 1549, Los Angeles, Calif.
Don Palmer, Douglas 2-4032, San Francisco, Calif.

CHEMICAL ENGINEER OR PETROLEUM ENGINEER

To direct product research on oil and gas field equipment. Engineer should have several years' experience in natural gas or petroleum processing and possess a good background in thermodynamics.

This important position offers excellent opportunity for professional advancement for an ambitious, creative engineer.

Please send complete information and photograph to:

Orval W. Groves,
Employment Supervisor
BUTLER MANUFACTURING COMPANY
7400 East 13th Street
Kansas City 26, Missouri

PHYSICAL CHEMIST CHEMICAL ENGINEER

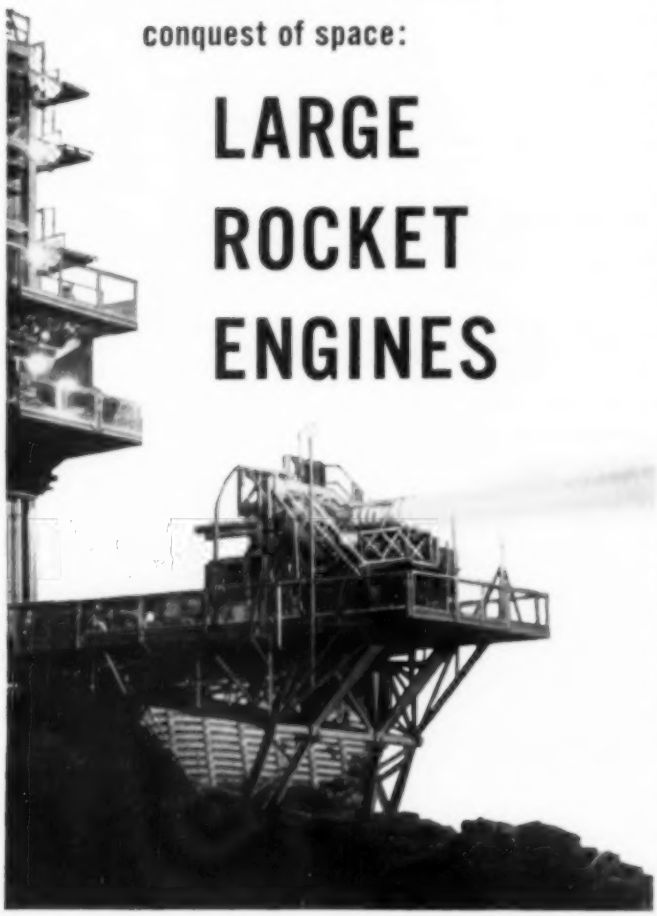
Openings in product development. A background in paper chemistry, in phenolic resins, or in electrochemistry would be helpful. Location near Boston. Please send resume to:

Mr. J. R. Thomas
Dewey and Almy Chemical Company
(Division of W. R. Grace & Co.)
62 Whittemore Avenue
Cambridge 40, Massachusetts

Wanted: Pioneers for man's last frontier

Help us build power for the conquest of space:

LARGE ROCKET ENGINES



Tomorrow's count down already fills the air at ROCKETDYNE's 1,600-acre Field Test Laboratory in the Santa Susana Mountains near Los Angeles. For this is the free world's largest workshop for rocket engineering—the great new industry that is now attracting many of the finest scientific and engineering minds in the country.

EXACTING RESEARCH, EXCITING PROSPECTS

From the rock-bedded test stands come 2 miles of recordings per day—data far ahead of available texts. The big rocket engine is a flying chemical factory in an absolute state of automation. It tolerates no error. It demands ductwork, turbomachinery, pressure chambers, orifices, injectors, heat exchangers and closed-loop control systems that must put hundreds of pounds of precisely mixed propellants into controlled combustion every second. Tolerances go down to 0.0001". Temperatures range from -250° F to 5000° F. Process time constants occur in "steady state conditions" of the order of a few milliseconds. Event sequences are minutely evaluated, as basis of designed performance predictions of extreme exactitude.

The methods now being developed at ROCKETDYNE for producing effective power to the limits of mechanical stress will have wide application. Such experience is practically unobtainable anywhere else. As a graduate engineer, *you* may be able to participate—now.

What motivates a rocket engineer? Well, the material advantages are high; but it is the work itself that draws him most. He feels the same incentive that moved Magellan . . . spurred the Wright Brothers . . . and beckoned again to Goddard as he flew the first liquid rocket at Auburn, Mass. in 1926.

At ROCKETDYNE, you can do this kind of pioneering in a management climate that stimulates personal growth—and rewards it to the limits of your ability. Academically, too, you can grow with our financial aid; some of the nation's finest universities are close by.

INTERESTING BOOKLET: "The Big Challenge"—facts on design criteria and development approaches used at ROCKETDYNE. Write for your personal copy, specifying your degree and years of post-college experience. Address: A. W. Jamieson, Engineering Personnel Dept. 2-CEG, 6633 Canoga Ave., Canoga Park, California.

WILLIAM J. CECKA, JR., 35, aeronautical engineer, (Univ. of Minn. '43), was called from North American by the Air Force for experimental rocket work in 1944. On his return, he progressed rapidly: 1948, supervisory test job; 1950, group engineer, operations; 1953 engineering group leader; 1955, section chief of engineering test. Using our refund plan, he has his M.Sc. in sight.

GEORGE P. SUTTON, in the 13 brilliant years since receiving his MSME, Cal Tech, has made rocketry a way of life. His reputation is world wide. His book *Rocket Propulsion Elements* is recognized as the standard text on the subject. Still active academically, but no bookworm, he takes time off occasionally to study the laws of motion at some of the world's better ski resorts.

ROCKETDYNE

A Division of North American Aviation, Inc.

BUILDERS OF POWER FOR OUTER SPACE

CHEMICAL & MECHANICAL ENGINEERS

are offered opportunity to advance professionally in diversified growth company

Air Products offers you the opportunity to advance professionally and financially in the field of low temperature processing. The company is the leader in the engineering, design, manufacture, and construction of oxygen plants and systems for the separation of gases such as Oxygen, Nitrogen, Carbon Monoxide, Hydrogen, and other low boiling building blocks of the chemical industry. We must expand the entire organization to meet the increasing demands of the steel, metallurgical, and chemical industries.

The following opportunities are available at Air Products:

- **PROCESS DESIGN:** To apply thermo-dynamics, fluid flow, heat and mass transfer, distillation, absorption and adsorption to the commercial solution of complex gas separation problems.
- **ESTIMATING AND ECONOMIC EVALUATION:** To study and evaluate the economics of proposed systems and to estimate the cost of complete plants.
- **PROJECT ENGINEERING:** To coordinate the engineering, design and construction of complete plants.
- **MECHANICAL ENGINEERING:** To design turbines, pumps, engines and special machinery to operate at extremely low temperatures. To coordinate the manufacture, procurement, installation and operation of large compressors, drivers and other machinery for the processing of gases and liquids.
- **DESIGN ENGINEERING:** Process equipment, pressure vessels, piping, structural, plant layout, electrical, instrumentation.
- **CONSTRUCTION ENGINEERS:** Supervision, start up, and operation.
- **RESEARCH AND DEVELOPMENT:** To explore new horizons in processing and equipment design. Analytical, experimental, design, pilot plants.
- **SALES ENGINEERING:** To negotiate the sale of complete low temperature systems, for chemical, petroleum, metallurgical, industrial and government requirements.

Openings exist for all levels of experience. Training and rotation are provided. High salaries are combined with a profit sharing and bonus program. Professional development is encouraged—growth is continually creating new managerial positions.

This well diversified company offers an unusual challenge for engineers who seek a professional career in the atmosphere of a dynamic, growing company.

Write in confidence to learn more about our Company.
B. H. VanDyke, Air Products, Inc., P.O. Box 538, Allentown, Pa.

Air Products
. . . INCORPORATED
P.O. Box 538 Allentown, Penna., U.S.A.

ENGINEERS

Process

Assignments in our Process Engineering Department for engineers with three to six years experience range from integrated refineries and chemical plants through all types of individual process units. The work includes heat and material balance, and computations for unit operations such as fractionation and heat-transfer. Send a summary of your experience and interests to F B Stratford, Head of Personnel, C F BRAUN & CO, Alhambra, California.

CHEMICAL ENGINEER

for

Plastics Process Engineering

MS in Chemical Engineering or equivalent, with 1 to 3 years experience preferred. To carry out a research or process design program requiring pilot plant experimentation, evaluation of results, design of new equipment, and technical supervision for new plant start-ups.

The diversity of Celanese's operations in the plastics, chemical and textile fields provides stability; advancement is assured by the company's planned expansion, and through the increasing importance of plastics in industry today. Please send complete details of background, experience and salary requirements to G. M. Hewitt.

Celanese
CORPORATION OF AMERICA
Morris Court
Summit, New Jersey

Opportunity

Naphthol and Fast Base Chemist preferably with practical production knowledge and experience to work out of the country for one year in one definite location followed by permanent position with large chemical company in U.S.A. Appropriate compensation and living expenses while abroad provided. Please reply to Box 1-2.

Process Engineer

IF you are growth-minded
IF you have a solid background in practical chemical engineering
IF you are under 32
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CHEMICAL ENGINEER—P.E., Age 41. Sixteen years' organic, inorganic, development, design, project, administration. Ten years' steady advancement in present employment; must leave for further advancement. Box 7-2.

PRODUCTION MANAGER—Graduate chemical engineer. Experienced in production, industrial chemicals for textile and metal processing trades. Polyvinyl acetate polymers, synthetic detergents, esterification, related specialties. Familiar all phases factory management. Opportunity first, location second. Box No. 8-2.

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CONSULTING CHEMICAL ENGINEER available on contract basis for economic analyses, engineering studies, process design, and start-up assistance of petroleum and chemical plants. Sixteen years' theoretical and practical experience in distillation, absorption, extraction, heat transfer, thermodynamics, instrumentation, industrial water treating, etc. Box 10-2.

CHEMICAL ENGINEER—Desire management position preferably with small or medium size company. Twenty-five years' progressive supervisory experience in research, production, process design and construction. Well grounded in all engineering phases of plant operation. Box 11-2.

CHEMICAL ENGINEER—B.S. 1955, veteran. Nineteen months experience in development as project engineer. Age 26, married. Desire production, pilot plant, or process development, with good growth potential. Box 12-2.

CHEMICAL ENGINEER FOR OVERSEAS SALES—B.S.Ch.E., 1955, age 29. Desire position that leads to technical sales engineer overseas. Good background chemistry, unit operations, equipment. Currently equipment application engineer. Married, veteran. Box 13-2.

CHEMICAL ENGINEER—Experience in statistical quality control; product, process, production and pilot plant development. Would consider pilot plant development, management liaison, or polymerization and plastic areas. Present salary $7400. Age 31. B.Ch.E., P.E. Married. Box 14-2.

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CHEMIST—Austrian graduated, recently immigrated, many years' experience in analytical chemistry. Box 17-2.

CLASSIFIED SECTION RATES

Advertisements in the Classified Section are payable in advance at 20¢ a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section agree that all communications will be acknowledged; the service is made available on that condition. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

the chemical engineer in MARKETING

(*Continued from page 139*)

Taft

George H. Taft, chemical consultant, has been named sales representative for the Industrial Processing Equipment Division of the Strong-Scott Mfg. Co., Minneapolis, Minn.

Mixing Equipment Co. announces three executive appointments. **Lewis H. Mahoney** will be director of technical sales; **James A. Mason** is advanced to chief application engineer; and **Donald M. Rowe** will become senior application engineer.

Cocks

New New York district sales manager of Johns-Manville's Celite Division to be **C. A. Cocks.** Mr. Cocks has been with Johns-Manville since 1939.

William A. Bours, III, assistant director of sales of the "Kinetic" Chemicals Section of Du Pont, elected to board of directors of the Air-Conditioning and Refrigeration Institute. Mr. Bours is treasurer of the Philadelphia-Wilmington Section of the A.I.Ch.E.

Sales manager of Norton Company's newly-formed Electro-Chemical Division will be **Frank B. Huke.** Mr. Huke served on the Manhattan project as a chemical engineer during World War II.

Necrology

Harold John Frederick Gourley, 70, president of the Institution of Civil Engineers, London, England. Mr. Gourley was senior partner of Messrs. Binnie, Deacon & Gourley, consulting engineers.

William B. Gery, 60, director of the Industrial Technical Division, Dorr-Oliver, Inc. Mr. Gery had been a member of the Dorr-Oliver staff for more than thirty years and a member of A.I.Ch.E. for more than twenty-five years.

Raymond E. Kirk, 66, Dean of the Graduate School of the Polytechnic Institute of Brooklyn. Dr. Kirk was considered one of the nation's leading chemical educators.

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OF ADVERTISERS

C.E.P. Advertising Offices

New York 36—Lansing T. Dupree, Adv. Mgr.; John M. Gaede, Asst. Adv. Mgr.; Paul A. Jalcuvar, Dist. Mgr.; Donald J. Stroop, Dist. Mgr.; Hale H. Carey, Dist. Mgr.; 25 W. 45th St., Columbus 5-7330.

Chicago 11—Richard R. Quinn, Dist. Mgr., 612 North Michigan Ave., Room 507, Superior 7-0385.

Cleveland 15—Eugene B. Pritchard, Dist. Mgr., 1836 Euclid Ave., Superior 1-3315.

Pasadena 1, Calif.—Richard P. McKey, Dist. Mgr., 465 East Union St., Ryan 1-8779.

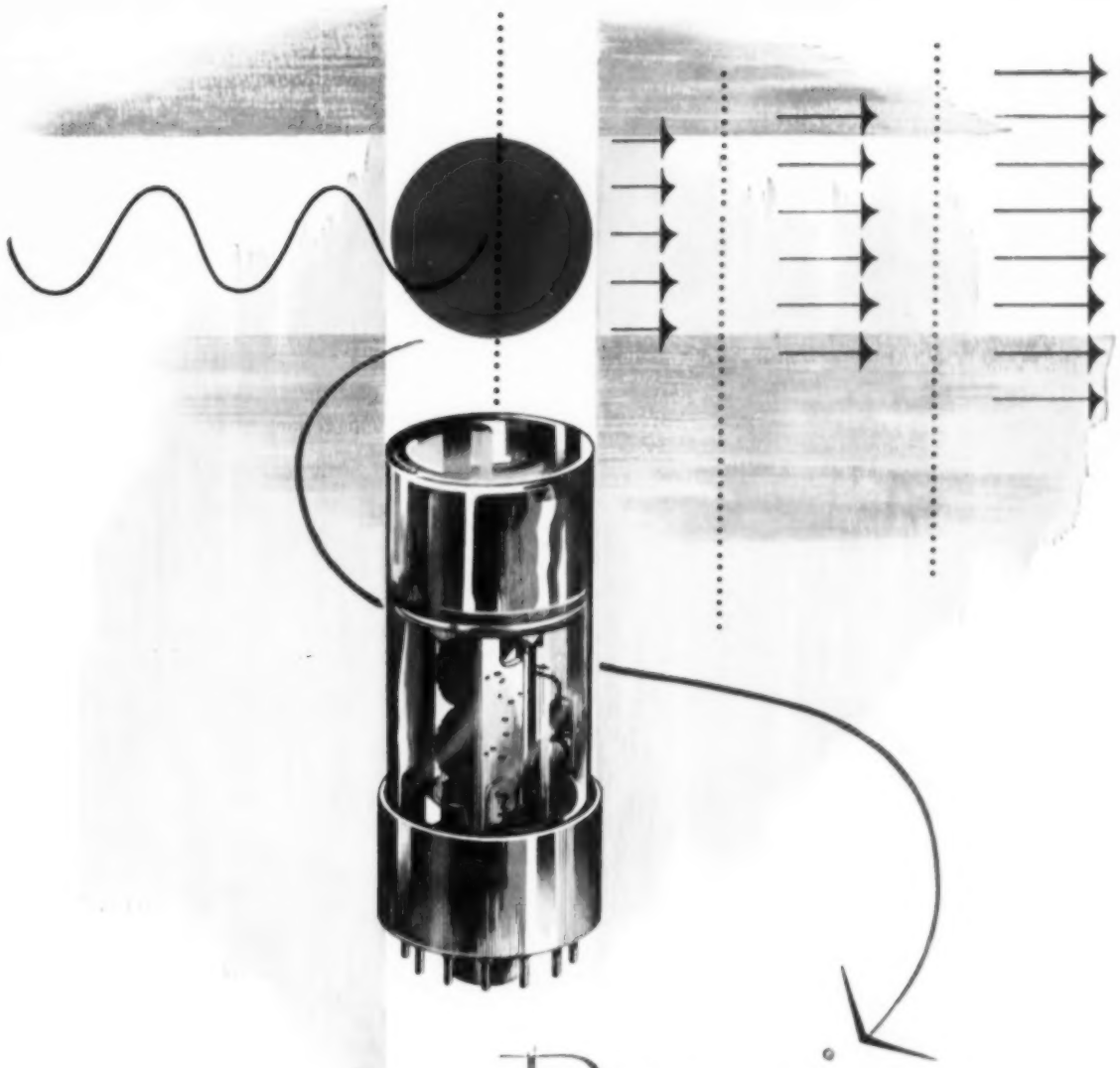
Dallas 28—Richard E. Haierman, Dist. Mgr., 2831 El Capitan Drive, Davis 7-3630.

Birmingham 8, Ala.—Fred W. Smith, Dist. Mgr., 1212 41st St., B.H., 57-6806.

news and notes of A.I.Ch.E.

1957 started with a particularly busy Executive Committee session preceding Council's January meeting . . . Most discussed was student membership . . . On this matter the Executive Committee had been charged with determining a policy & there were so many different opinions that this is currently the "hot potato" & Executive wants to juggle it a while longer . . . It is now scheduled for deliberation at the White Sulphur Springs Meeting, March 3-6 . . . If any member has strong opinions on student & student-chapter membership, will he please send them to me before March. . . . Year's end always brings with it a tremendous pile-up of business for Council . . . Committee work is geared to a final report for the December Annual Meeting, which usually places a number of policy matters on the agenda for the last meeting & the carry-over is felt in Council business in January . . . Hardly had the minutes of the December meeting been digested when Council was deluged for its January 19 meeting with reports from various *ad hoc* committees & study groups . . . Last year the **Idaho Section** became concerned about varying interpretations by the **Bureau of Internal Revenue** on whether money received to cover expenses in moving from one job to another was taxable . . . The section referred the problem to Idaho's senators & representatives . . . Now it has come before the Executive Committee from yet another source . . . The matter involves all persons, not only engineers, who are recompensed for the cost of moving from one job to another & have had such expense money declared taxable but not deductible . . . It was decided that A.I.Ch.E. representatives should bring this problem to the attention of Engineers Joint Council to see whether a concerted movement by the whole engineering profession would clarify these matters. . . . In legislation such as this where a government department or representatives are asked to act on some matter by a Local Section, Council has always urged careful consideration . . . Just recently a **policy memorandum on "political action"** was sent to local sections & for those who have not seen the note it is digested here . . . On matters which affect chemical engineering or professional standards Council feels it proper to let the views of interested groups be known . . . The following check points however must be carefully noted . . . Feelings expressed must be those of the majority of Local Section members; the opinions must be clearly represented as coming from the local, not National, membership; action should be plainly in the public interest & should coordinate with & complement views expressed by A.I.Ch.E. nationally or jointly with other engineering groups, such as Engineers Joint Council . . . In matters that are not related to the objectives of the Institute, Council feels that Local Sections should be cautioned against expressing views as A.I.Ch.E. groups. . . . Executive Committee also appointed three alternates to the **Perkin Medal Committee:** R. H. Wilhelm, Princeton University; L. C. Kemp, The Texas Company; & W. W. Kraft, the Lummus Company . . . & on recommendation of the Program Committee approved Northwestern University as the site for the **1958 Heat Transfer Conference,** which will be held in cooperation with A.S.M.E. on August 18-21 . . . Council the next day heard major discussions from the **Professional Legislation Committee,** C. E. McCulloch of Foster Wheeler Corporation & J. F. Lawrence of The Lawrence Company, as A.I.Ch.E. representatives on E.C.P.D.-E.J.C. Joint Committee on Practice of Engineering, presenting the problems facing them in their negotiations with the Joint Professional Committee for the Study of the New York State Education Law . . . The **Professional Development Committee** was represented by H. W. Schulz, Carbide and Carbon Chemical Corporation; F. E. Reese, Monsanto Chemical Company; & W. E. Keppler, Merck & Company, who presented several areas of professional development that they wish to explore & asked Council's opinion on the value of these areas to chemical engineering as a profession . . . Reporting also was the **Admissions Committee,** E. F. Jennings, Hercules Powder Company; Aimison Jonnard, Shell Chemical Corporation; & E. J. Lyons, General American Transportation Corporation, who discussed current problems of the Admissions Committee in trying to operate under the strict interpretation of the Constitution . . . For all three committees Council developed significant policy, which will be reported here after current minutes are approved. **Chairmen of Committees for 1957:** Awards, E. R. Gilliland; Nominating, W. G. Whitman; Professional Legislation, J. P. Cooke; Public Relations, Robert York; Research, W. E. Catterall; Sections Activities, G. E. Holbrook. . . . **Student Chapter Counselors:** H. B. Kendall for Case Institute of Technology, Frank P. May for University of Florida, David Dickinson for University of New Mexico, & L. C. Eagleton for University of Pennsylvania.

F.J.V.A.



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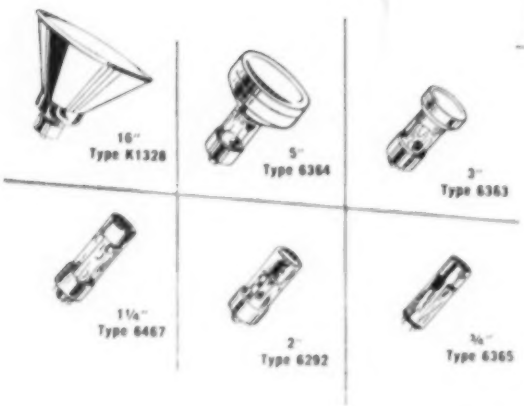

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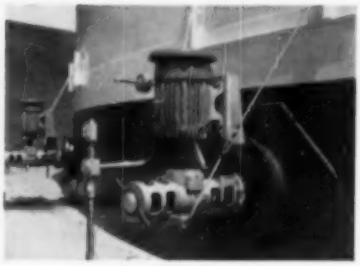

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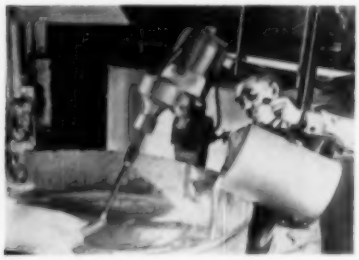

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